

Validation, Water and Energy

Global Modeling and Assimilation Office

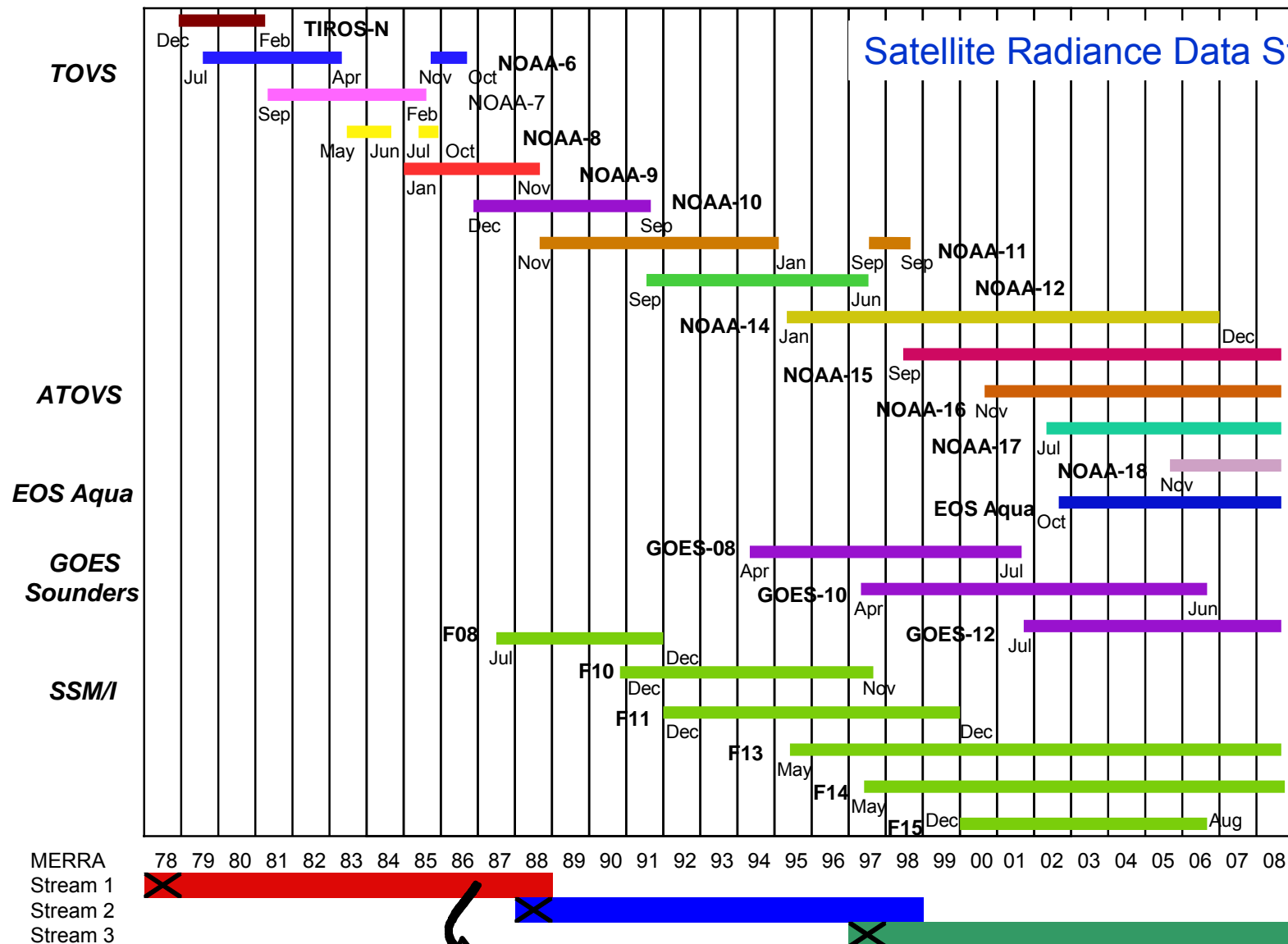
- ▶ Overview and Status
- ▶ Some early results
- ▶ Monitoring (time permitting)

Presented by Michael Bosilovich, GSFC, January 5, 2009

NASA's Modern Era Retrospective-analysis for Research and Applications (MERRA)

- ▶ Retrospective-analyses use a fixed Global Atmospheric Model and Data Assimilation System to analyze the historical satellite and conventional data records into a continuous global gridded data set including a multitude of ancillary weather and climate diagnostics
- ▶ MERRA uses the latest release of the GMAO Global Earth Observing System Data Assimilation System (GEOS-5) and will analyze the period from 1979 – present, assimilating satellite radiances and conventional observations
- ▶ A NASA contribution to CCSP Synthesis and Assessment Product 1.3: Re-analyses of historical climate data for key atmospheric features. Implications for attribution of causes of observed change.

Satellite Radiance Data Streams



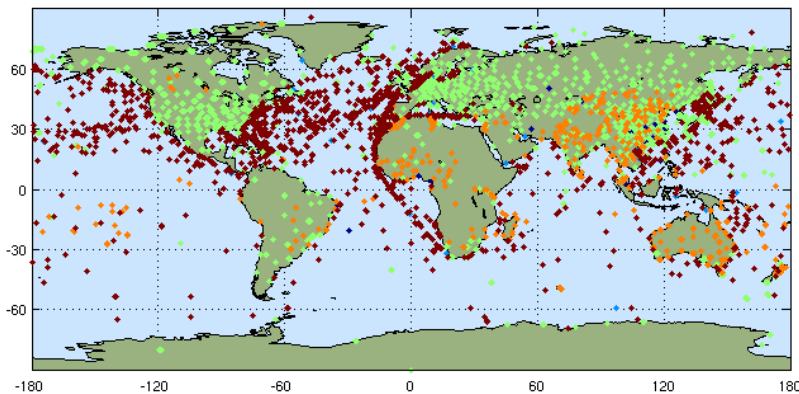
MERRA will analyze radiances from these satellites, and also several satellite retrieved data products as well as conventional observations (e.g. sondes)

The Changing Observing System

07-Jan-1973 12UTC All data: 77098 observations

all lat; all lon; all lev; all kt; all kx; all qc; all qch
/data/austin/b500_swp_73/all_ods_workdir/SAVE_ODS/b500_swp_73.ana.obs.19730107_12z.ods

Observation Locations

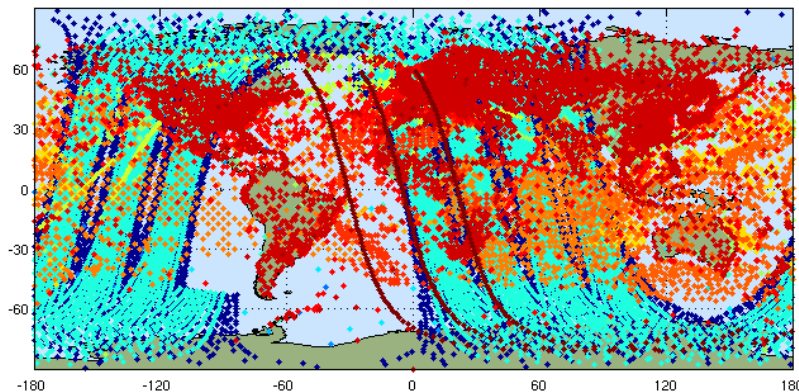


1973 – 77K Obs every 6hrs

07-Jan-1979 12UTC All data: 325765 observations

all lat; all lon; all lev; all kt; all kx; all qc; all qch
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Observation Locations

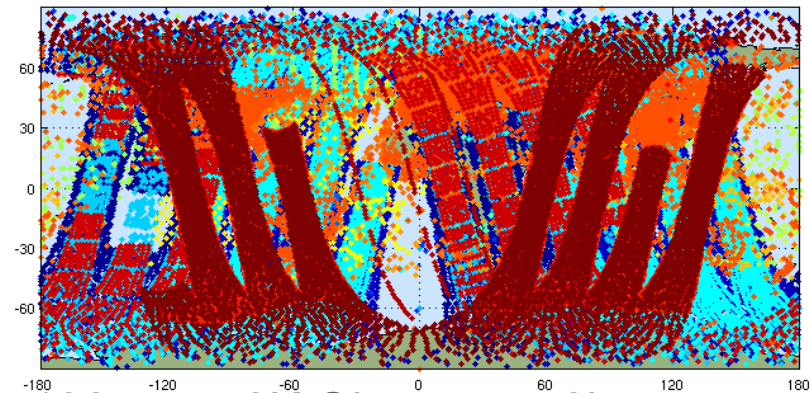


1979 – 325K Obs every 6hrs

02-Aug-1987 12UTC All data: 550602 observations

all lat; all lon; all lev; all kt; all kx; all qc; all qch
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Observation Locations

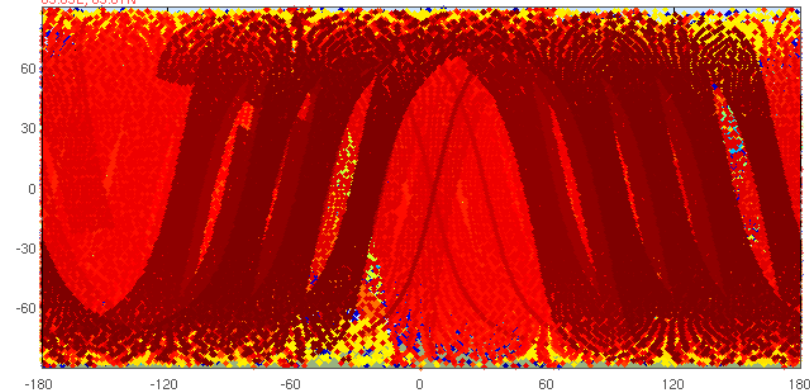


1987 – 550K Obs every 6hrs

07-Jan-2006 12UTC All data: 4217655 observations

all lat; all lon; all lev; all kt; all kx; all qc; all qch
/data/austin/d5_b10p9stab12_jan06/all_ods_workdir/d5_b10p9stab12_jan06.ana.obs.20060107_12z.ods

Observation Locations



2006 – 4.2M Obs every 6hrs

NASA's Modern Era Retrospective-analysis for Research and Applications (MERRA)

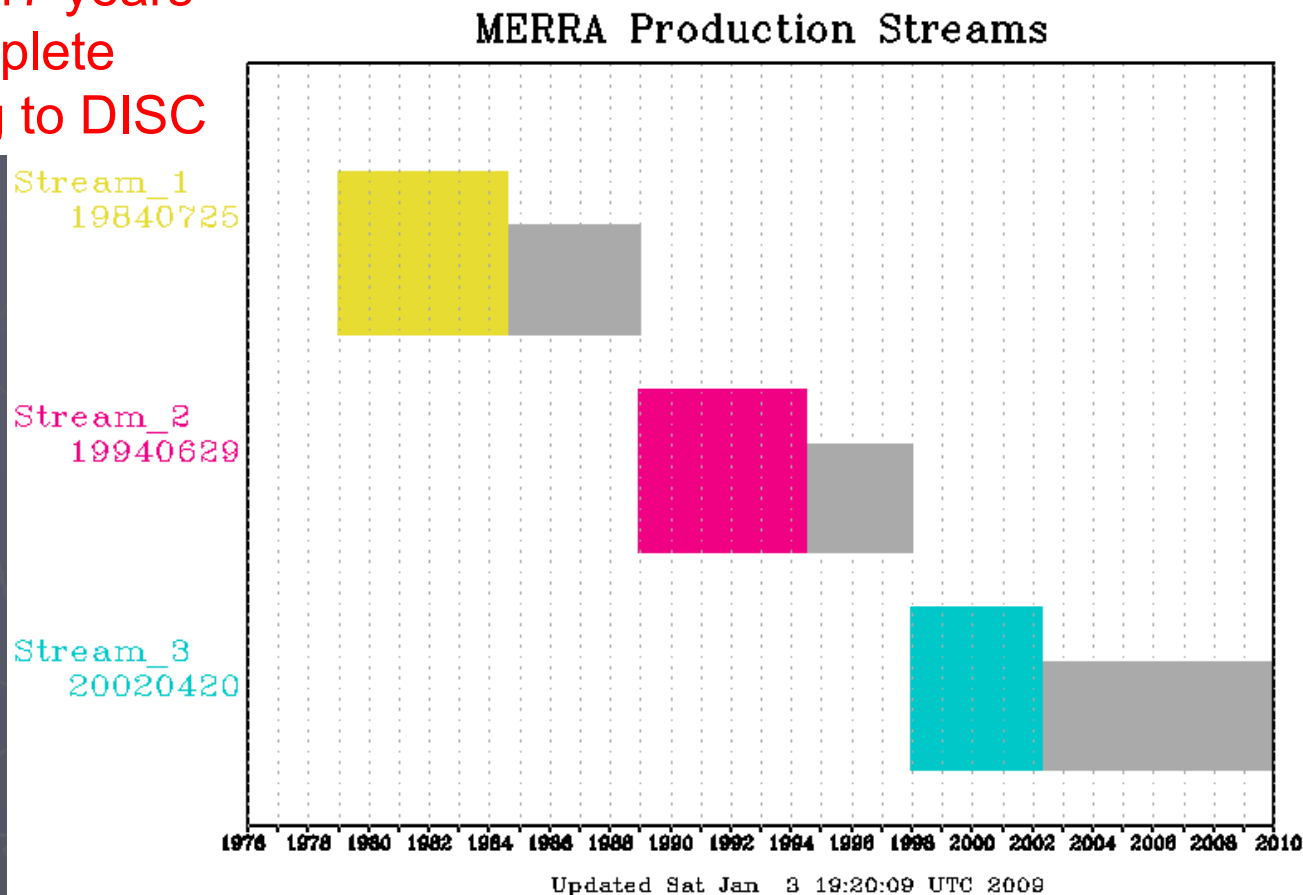
- ▶ Objective: To improve the water cycle representation in reanalyses, and support NASA Earth science and application activities
- ▶ 1979-present (continuing as it is feasible)
- ▶ $\frac{1}{2}^\circ$ horizontal resolution (72 model levels, sfc-strat)
- ▶ 1 hourly surface and 2D diagnostic data
- ▶ 6 hourly 3-Dimensional atmospheric analysis
- ▶ >150 Tbs online storage, many portals
- ▶ Production Began May 2008 (complete Fall-2009)
- ▶ Home - <http://gmao.gsfc.nasa.gov/merra/>
- ▶ Data - <http://disc.sci.gsfc.nasa.gov/MDISC/>
- ▶ Discussion - <http://merra-reanalysis.blogspot.com/>

MERRA Validation

- ▶ Experiment Review, Nov 2007
- ▶ Included Short Experiments at native resolution (9 months was the longest)
 - Long experiment with coarse resolution (Scout)
- ▶ Radiation, clouds, precipitation, surface temperature, UTH, general circulation
- ▶ Data sources: SRB, CERES, MODIS, GPCP existing reanalyses
- ▶ Increments (e.g. P-E), Indian Monsoon

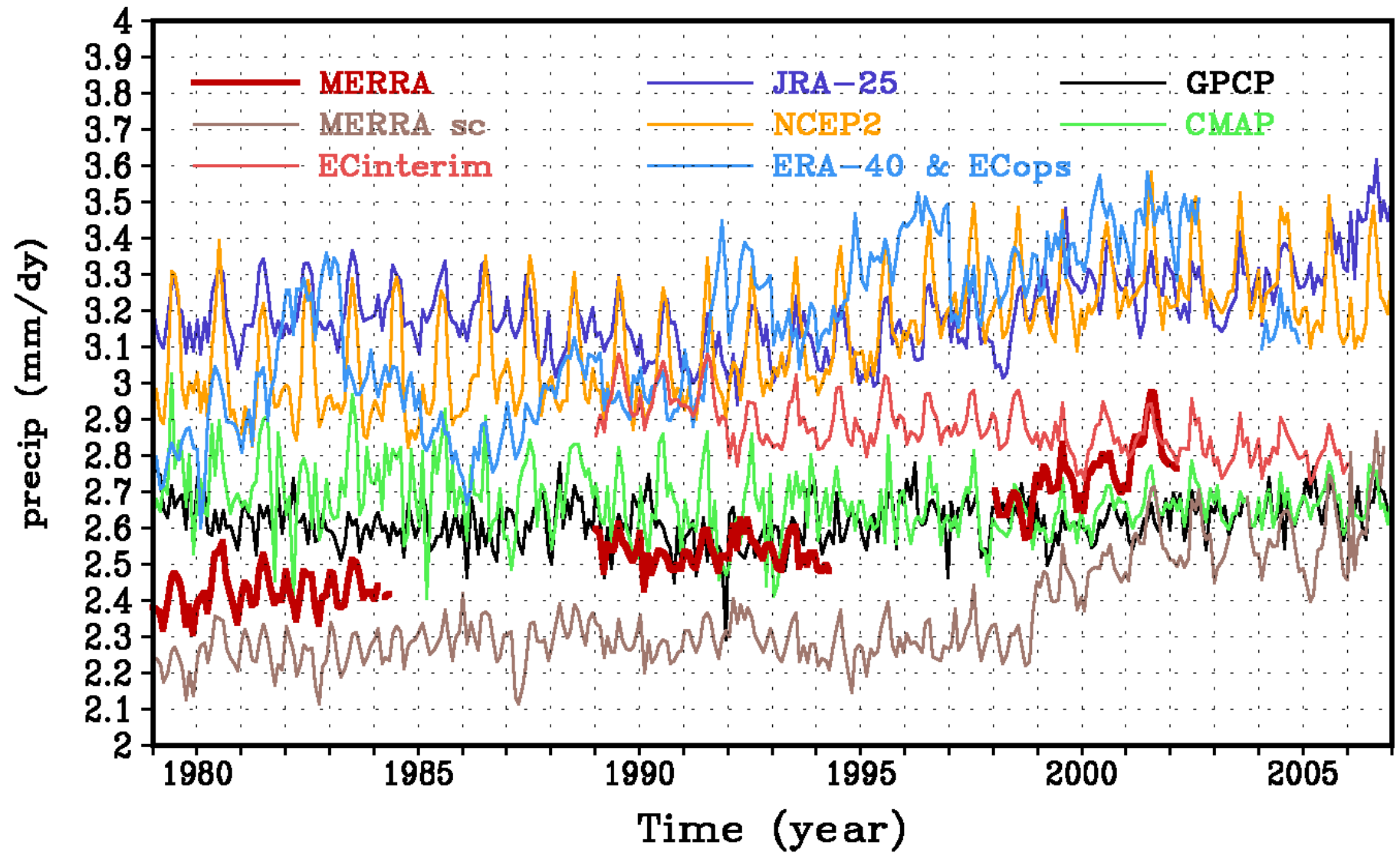
MERRA Production Status

Nearly 17 years
complete
shipping to DISC



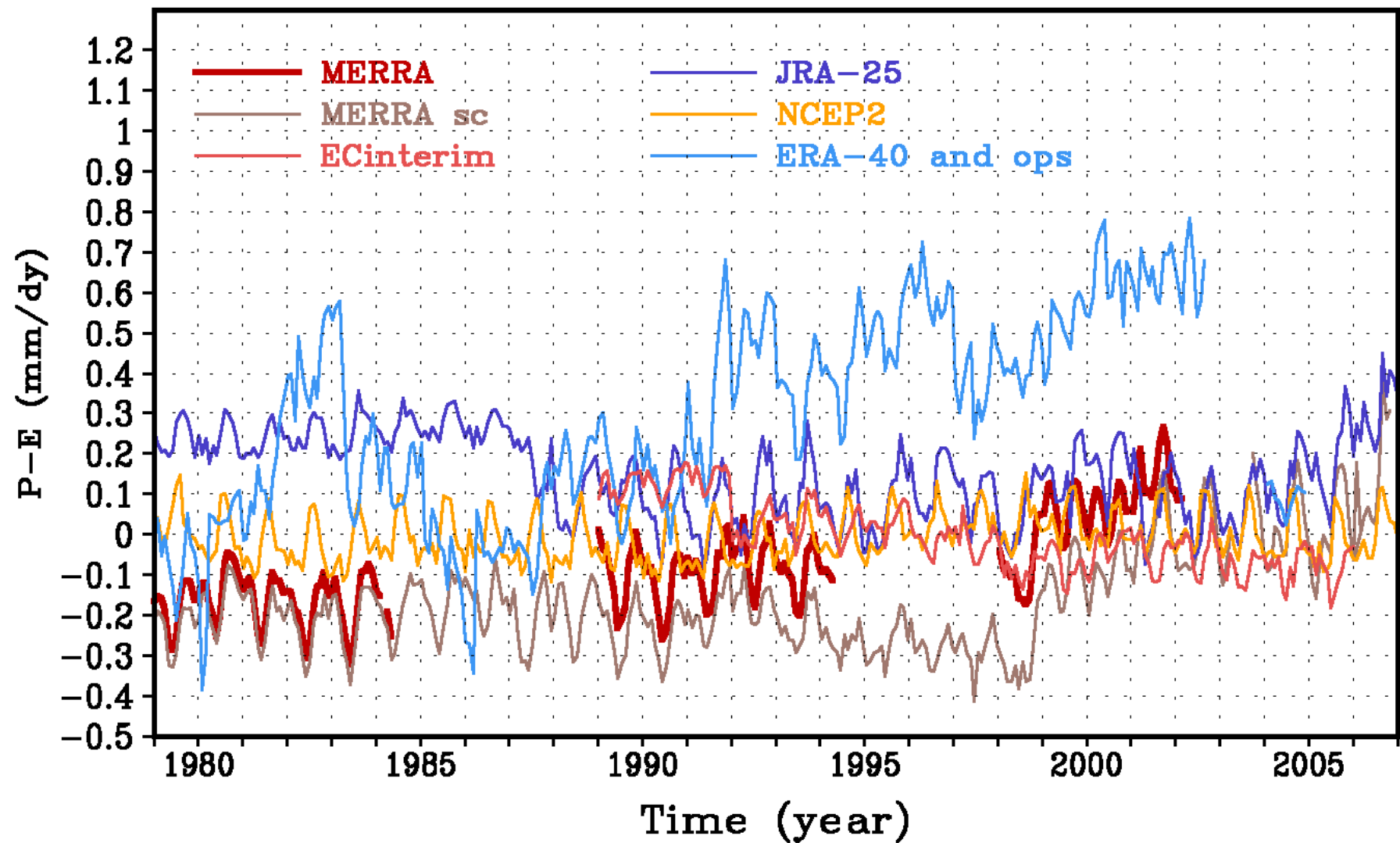
- This figure is updated regularly at:
<http://gmao.gsfc.nasa.gov/research/merra/progress-events.php>

Global mean precipitation

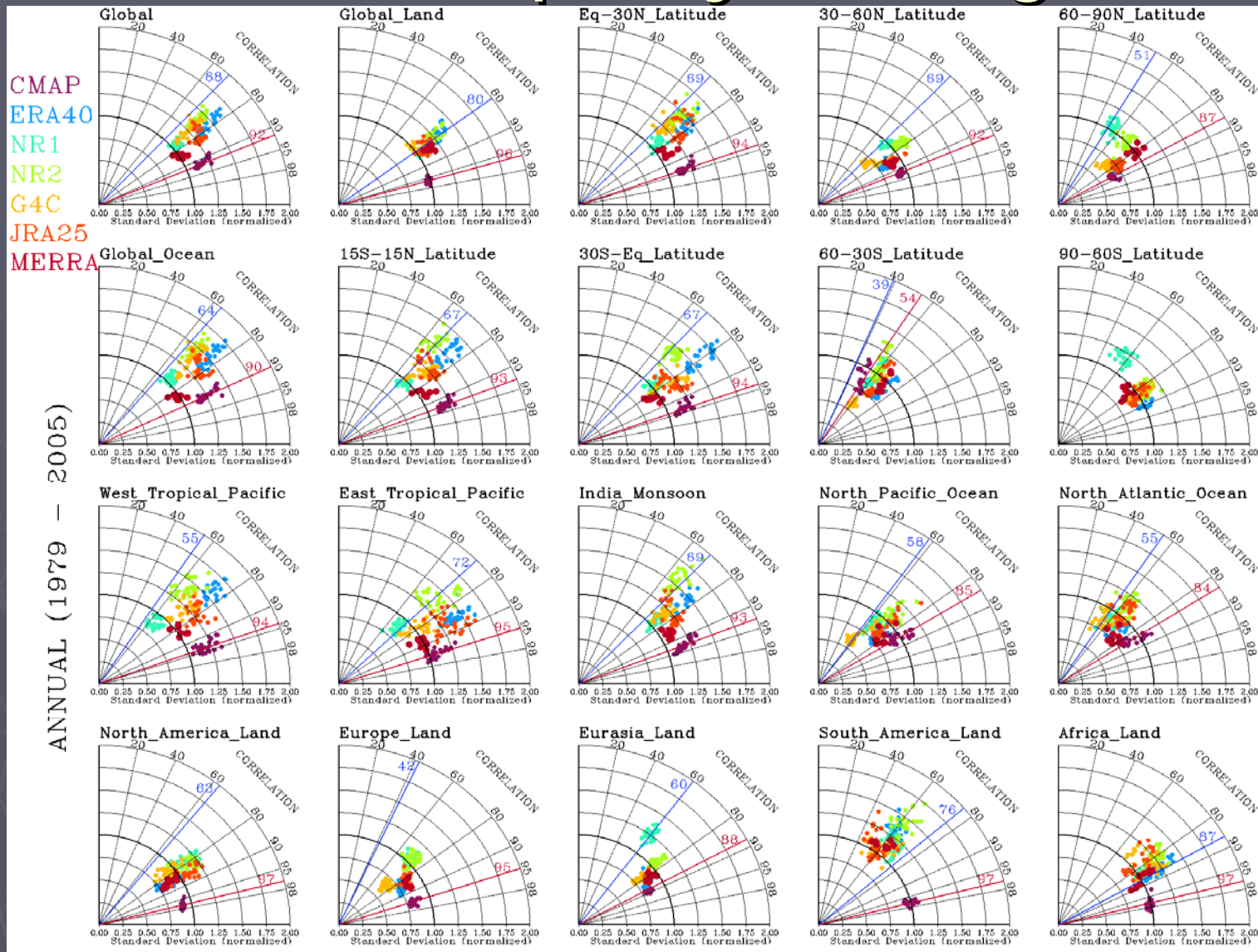


Effect of Water Vapor Analysis

Global mean P-E

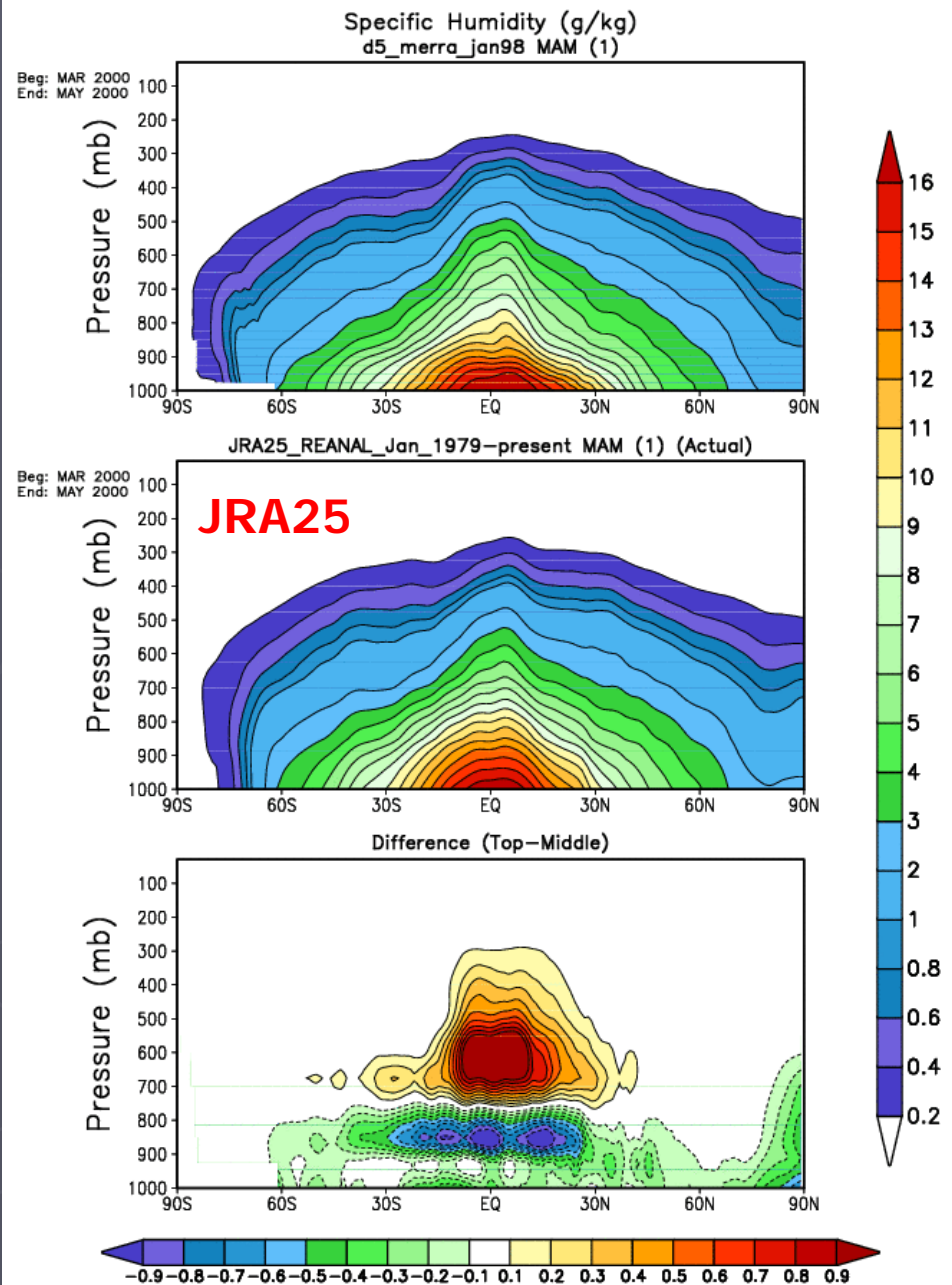
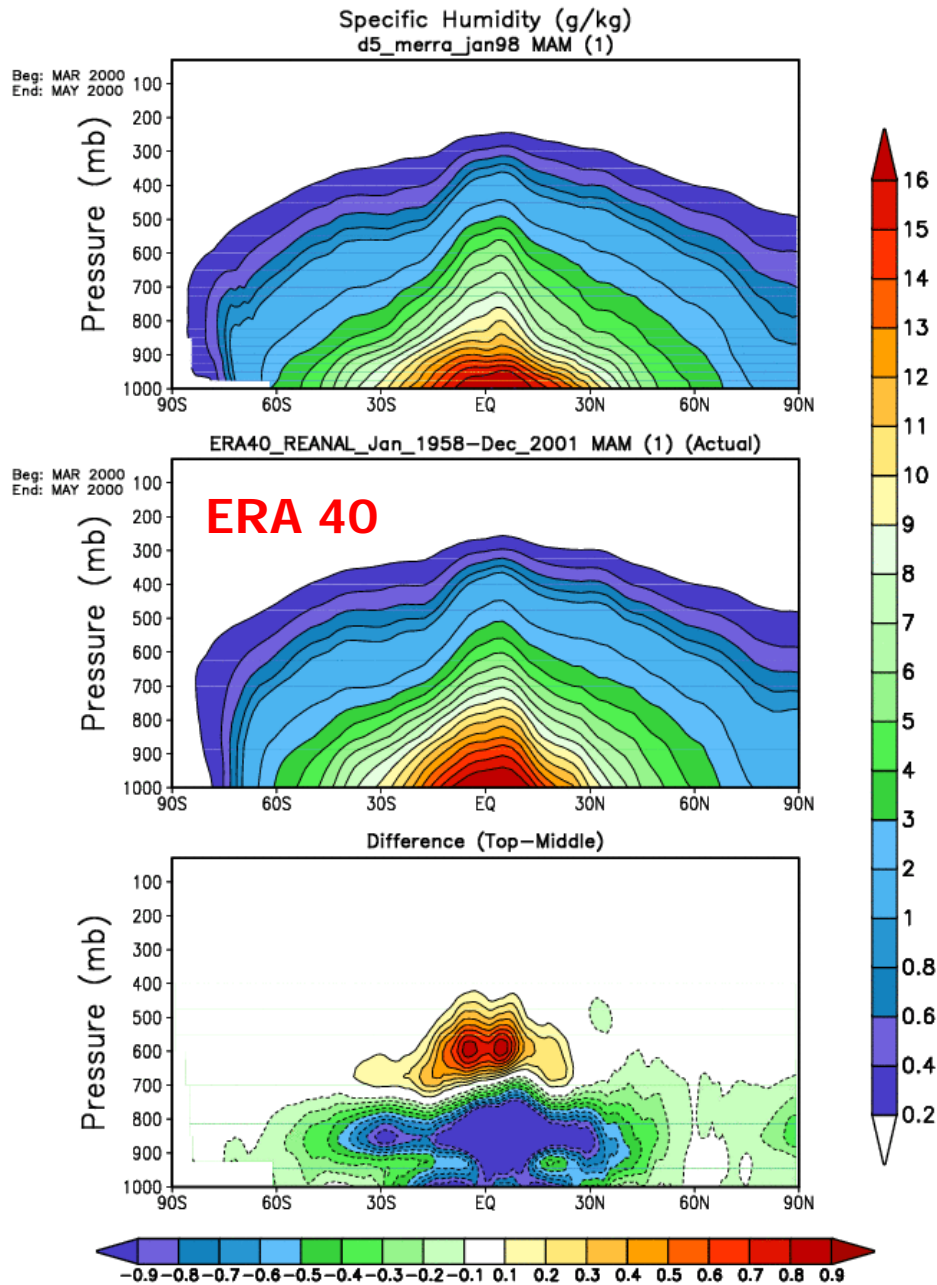


MERRA Precip Taylor Diagrams

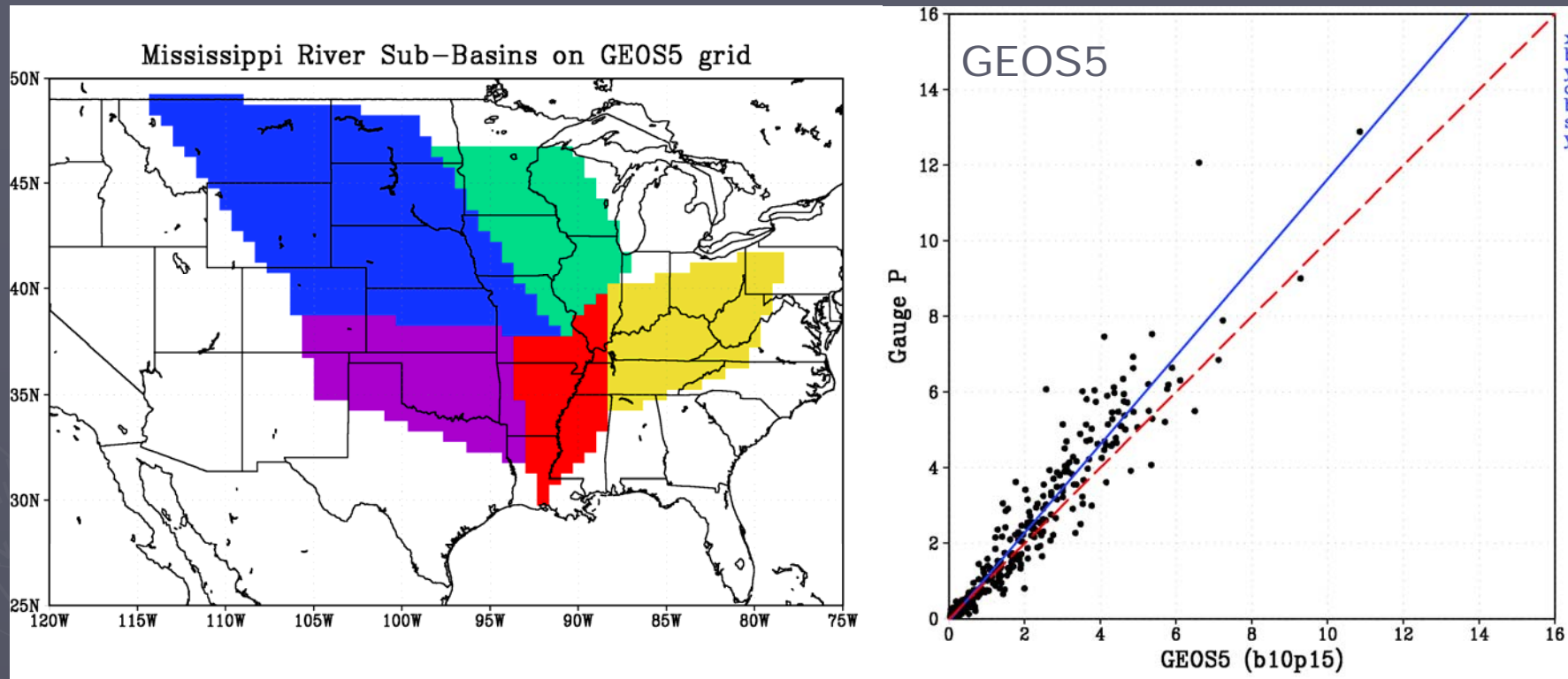


► See also: Bosilovich et al (2008, JAMC)

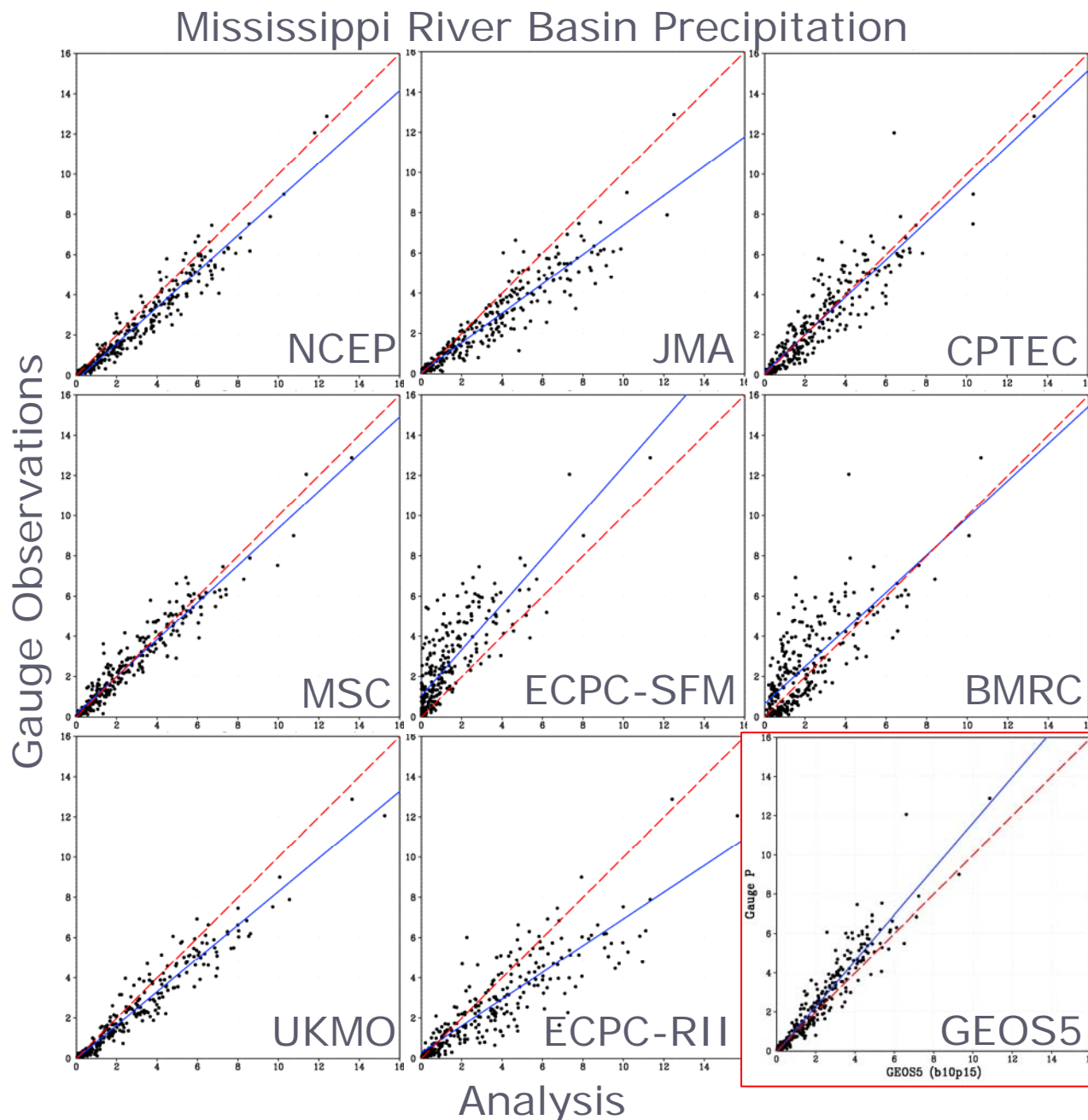
Zonal Mean Specific Humidity



Basin-scale Precipitation



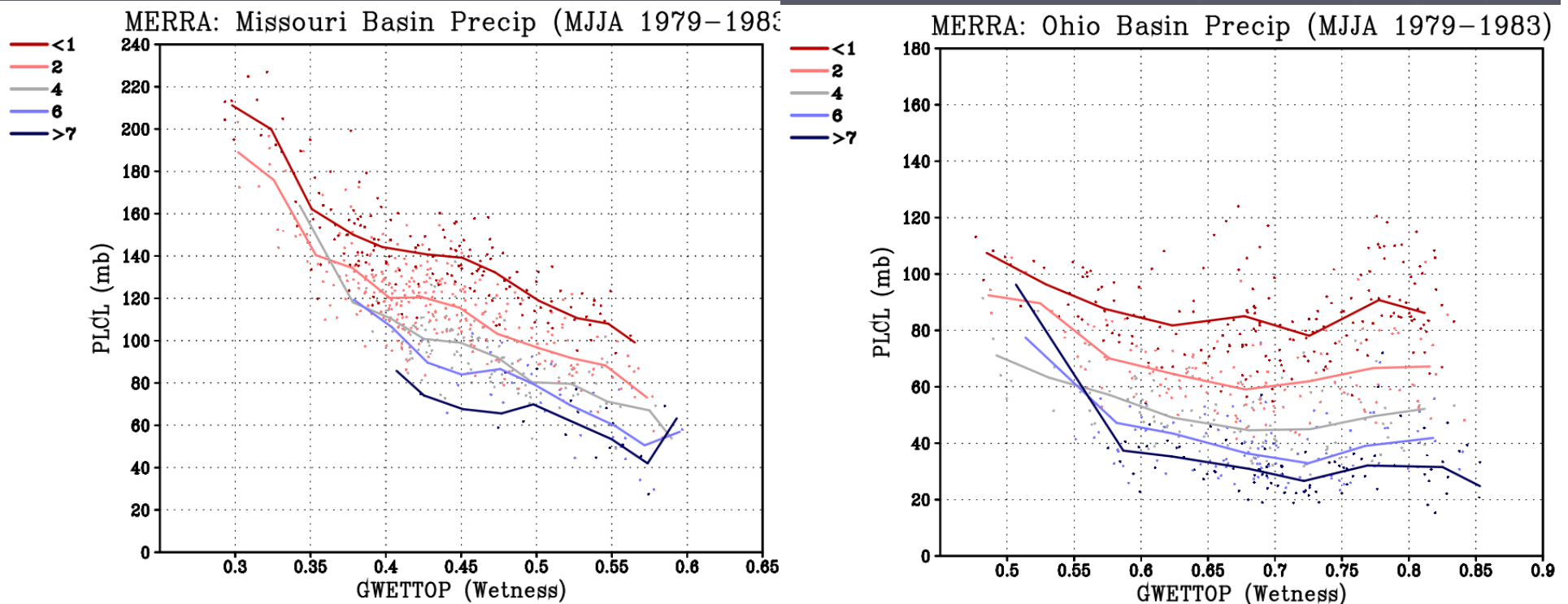
- ▶ CPC US $\frac{1}{4}$ gridded gauge data
- ▶ Daily, Jan 1 – Sep 30 2004
- ▶ Consider all of the Mississippi River Basin domain
- ▶ Comparison with CEOP Multi-Models in Poster session



Jan-Sep 2004 Daily MRB Precipitation

- ▶ MRB is in the heart of a data rich region for analyses
- ▶ Precipitation is independent (not assimilated)
- ▶ In general, Models have different characters
- ▶ Most overestimate high rain events
- ▶ BMRC excessively dry summer
- ▶ GEOS5 slight under estimate, but otherwise comparable with the best

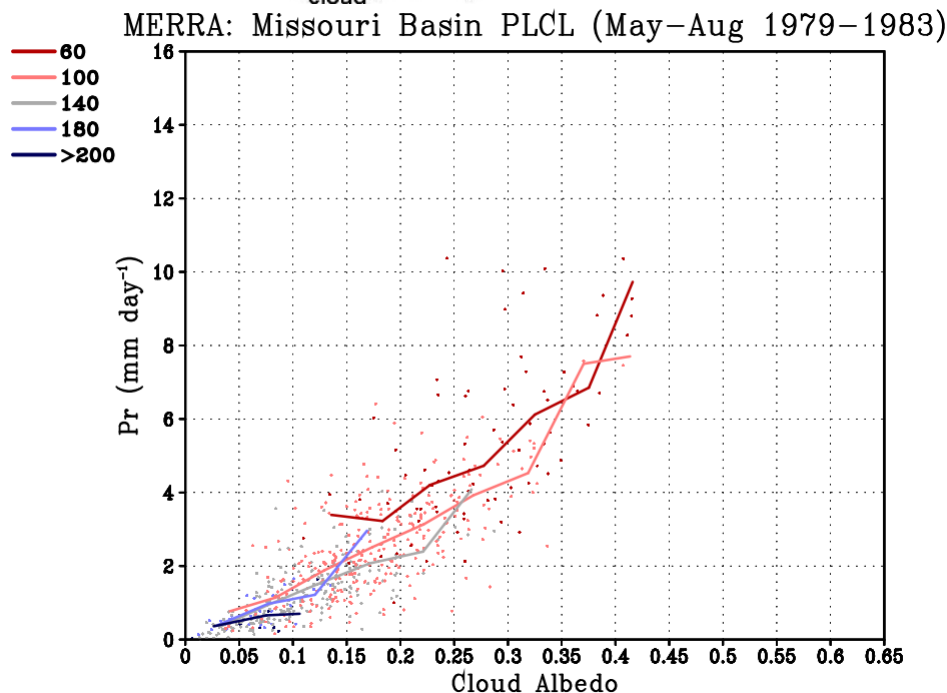
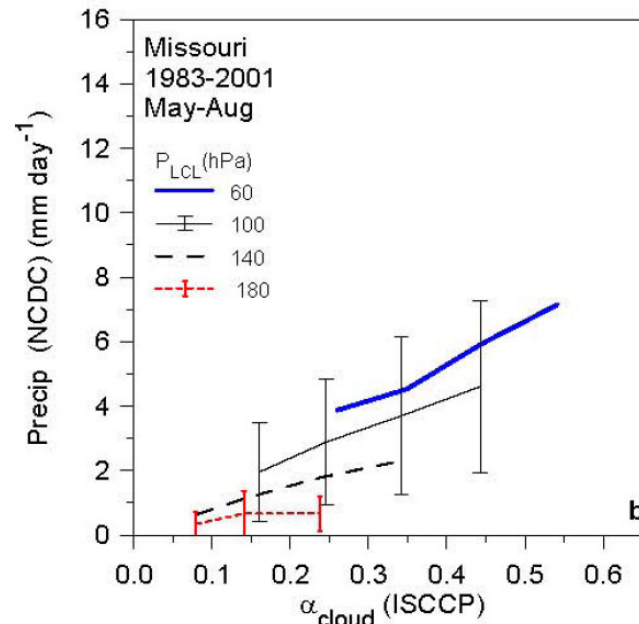
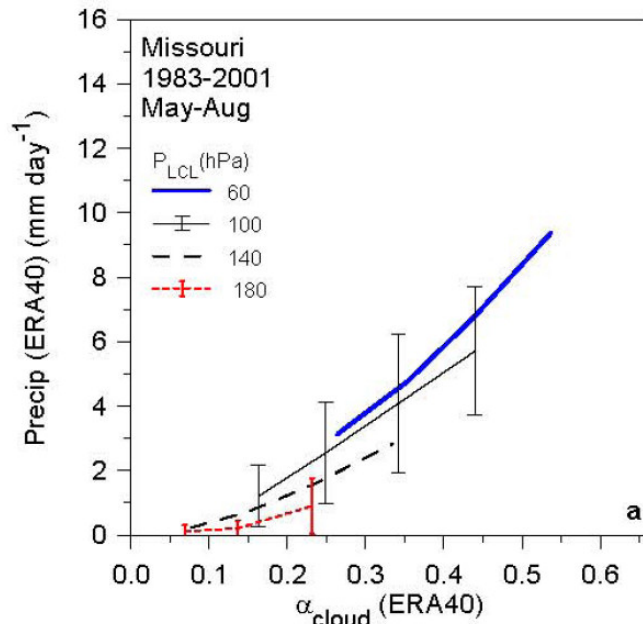
MERRA: Missouri and Ohio LCL, Wetness and Precip



Following A. Betts et al. compare soil wetness with LCL and precipitation to estimate land/atm coupling

The LCL is not sensitive to soil wetness over the Ohio, and a bit more over the Missouri

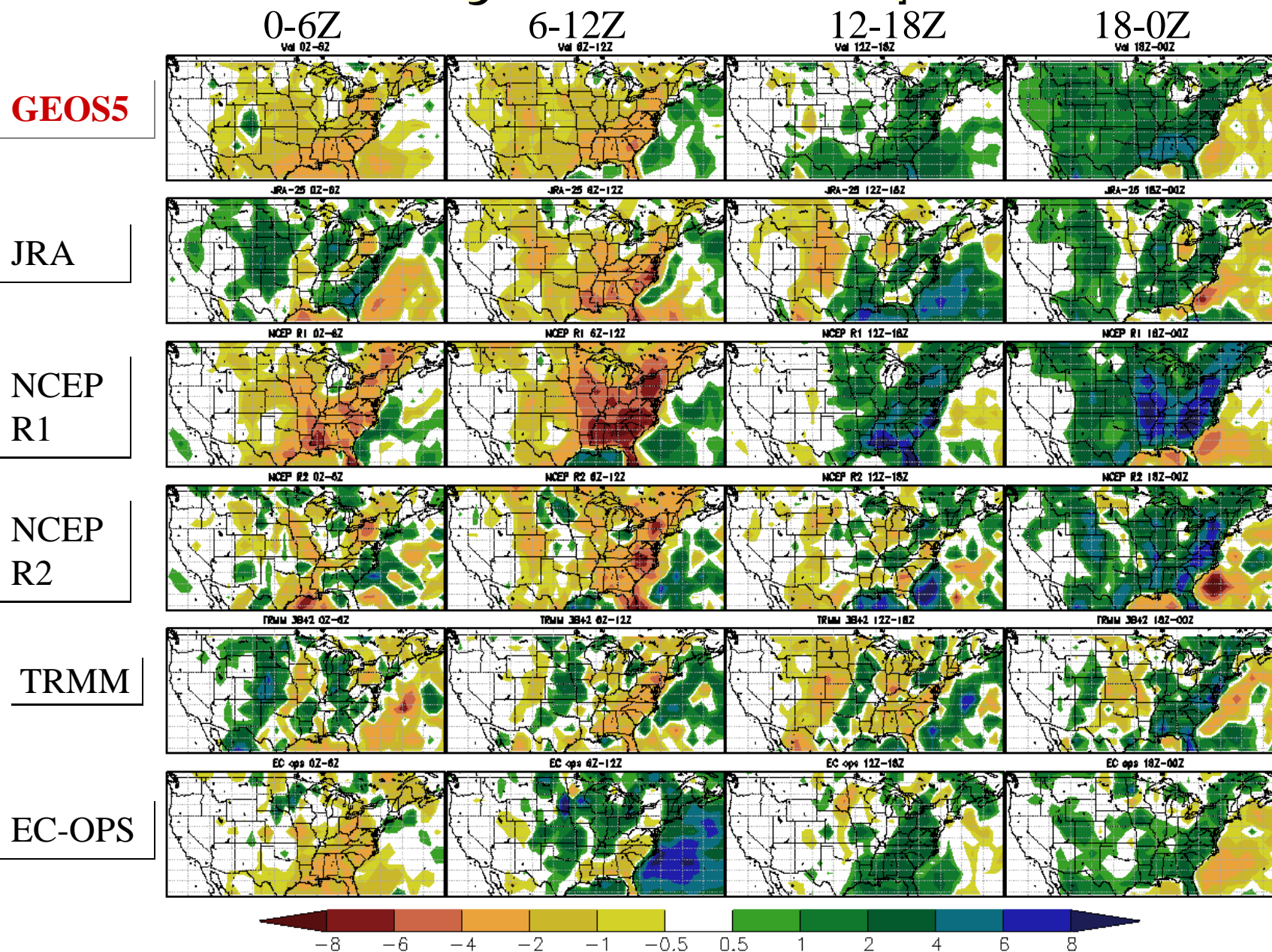
Cloud forcing to Precipitation



Cloud Albedo, a SW cloud forcing diagnostic (Betts et al)

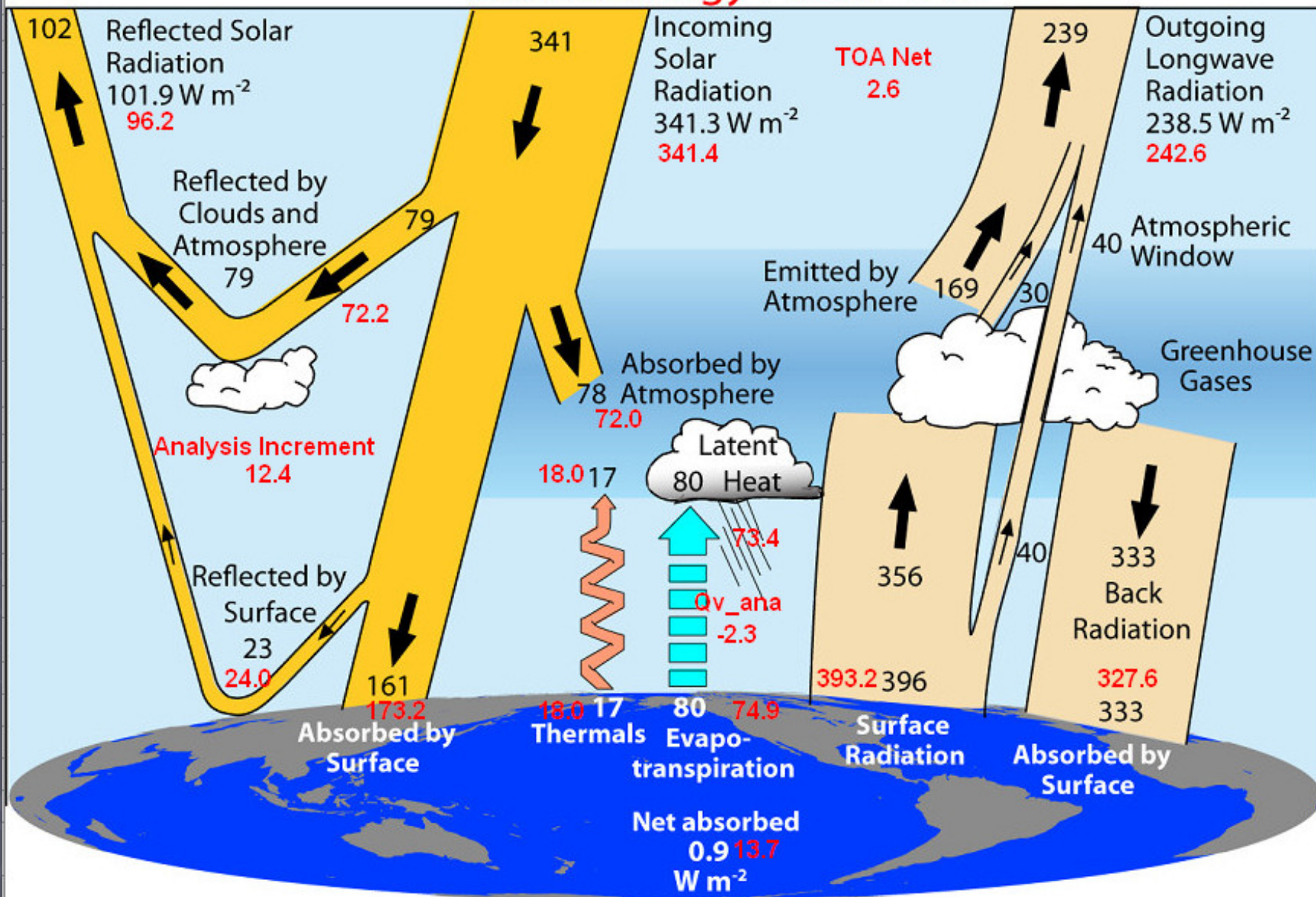
MERRA underestimates the maximum range of both ISSCP observations and ERA40 over the Missouri

Diurnal Cycle of Precipitation



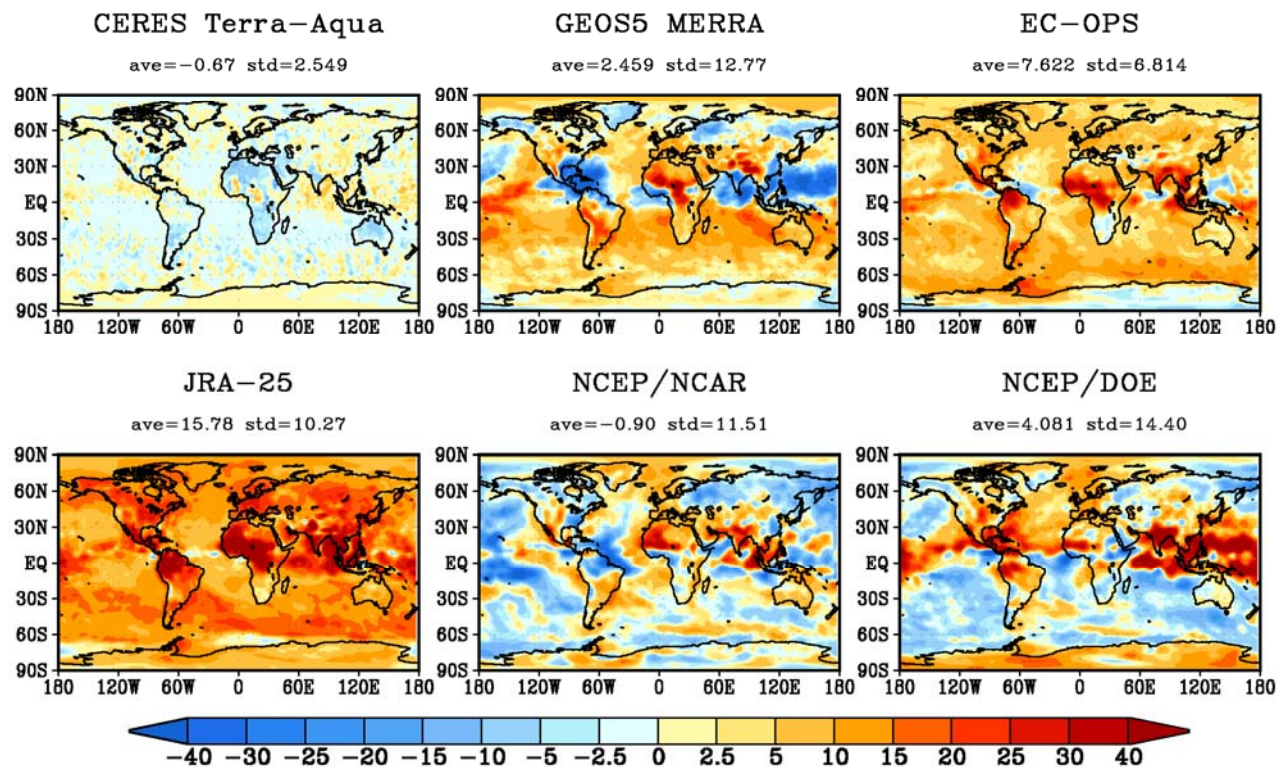
MERRA(RED) 179 Months

Global Energy Flows W m^{-2}



Background from Trenberth, Kiehl and Fasullo (2008, BAMS Accepted)

Jul 2004 TOA LW diff from CERES ERBE-like (W/m^2)



TOA LW comparison of reanalyses

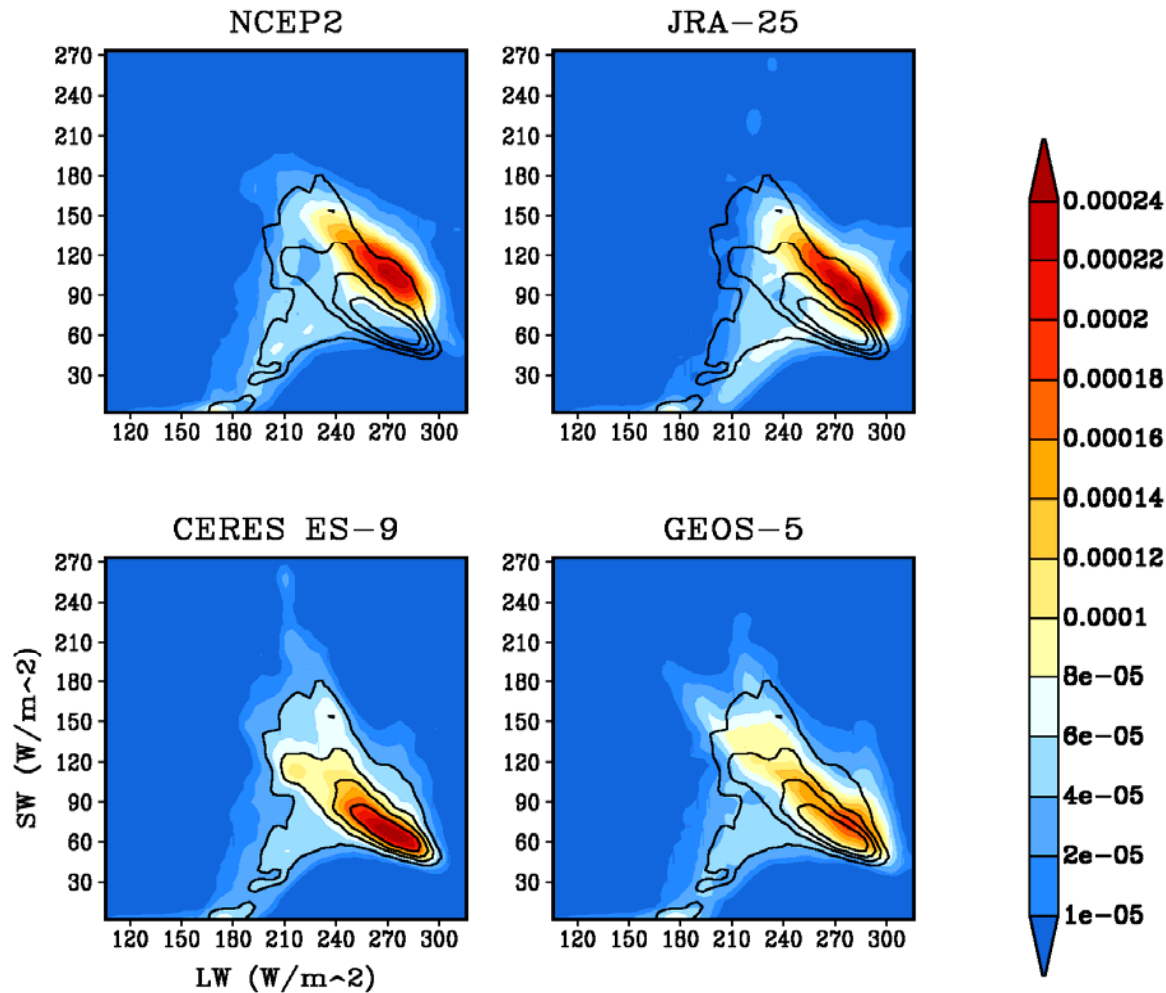
- All reanalyses get similar patterns as observation.
- The difference between observations can be a reference for the uncertainty in reanalyses.
- For all reanalyses, strongest error happens over tropical convective regions.
- MERRA TOA LW flux bias mean and standard deviation are moderate among reanalyses.

TOA LW difference (W/m^2)	Jan, 2004		Jul, 2004	
	Ave	STD	Ave	STD
CERES Terra - Aqua	-0.8	2.4	-0.7	2.5
MERRA - CERES	5.4	9.1	2.5	12.8
ECOPS - CERES	8.9	7.3	7.6	6.8
JRA25 - CERES	16.2	9.0	15.8	10.3
NCEP1 - CERES	-0.5	11.4	-0.9	11.5
NCEP2 - CERES	4.6	14.4	4.1	14.4

From Junye Chen

TOA LW-SW Joint Freq. Distribution

01/04–07/04 TOA LW–SW Joint frequency distribution



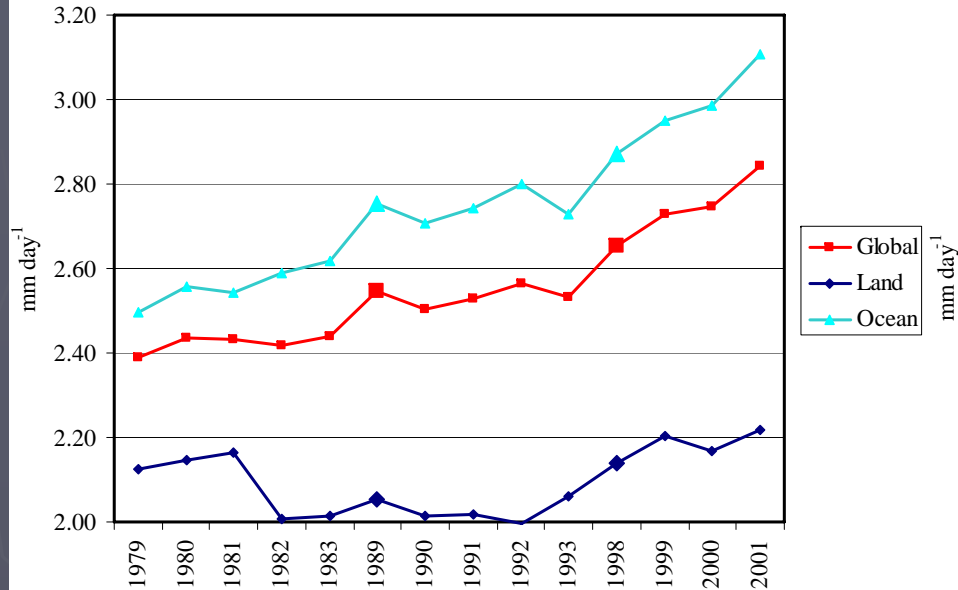
- LW-SW Joint Frequency Distribution (JFD) shows the relationship of LW and SW under different atmospheric states.

- The shape and location of MERRA LW-SW JFD is closer to CERES observation, while the MERRA pattern is a little stretched.

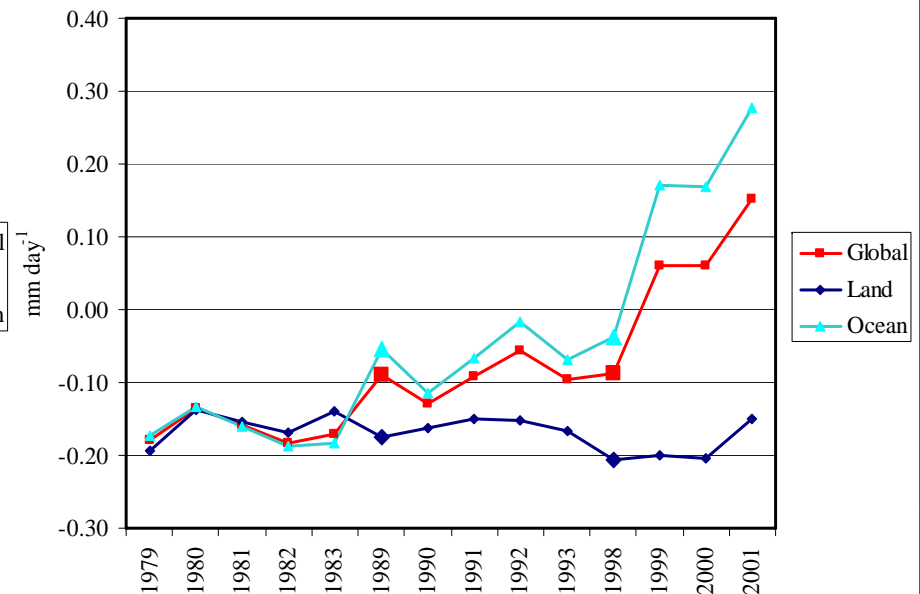
- From Junye Chen

Trends in the Water and Energy Cycles

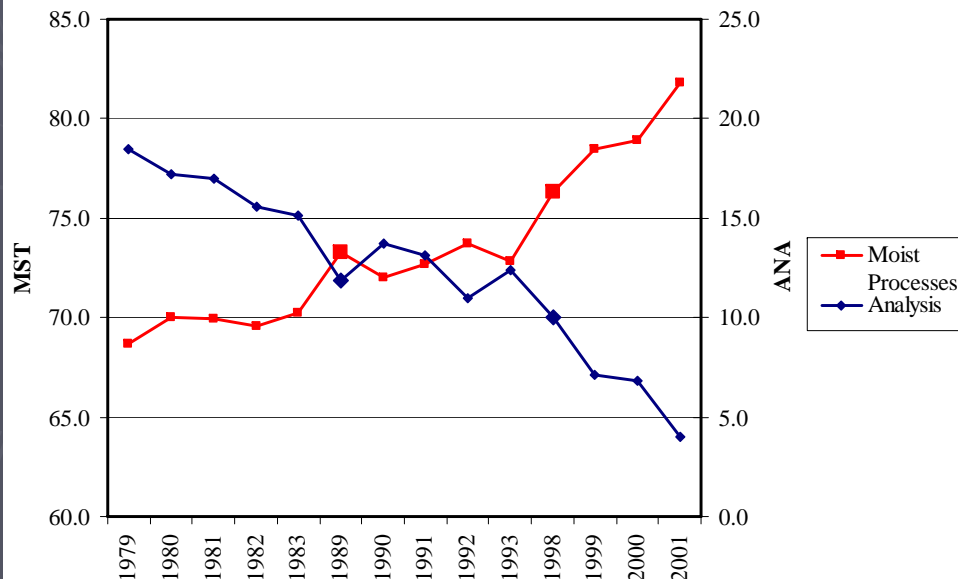
Precipitation



Water Vapor Increments

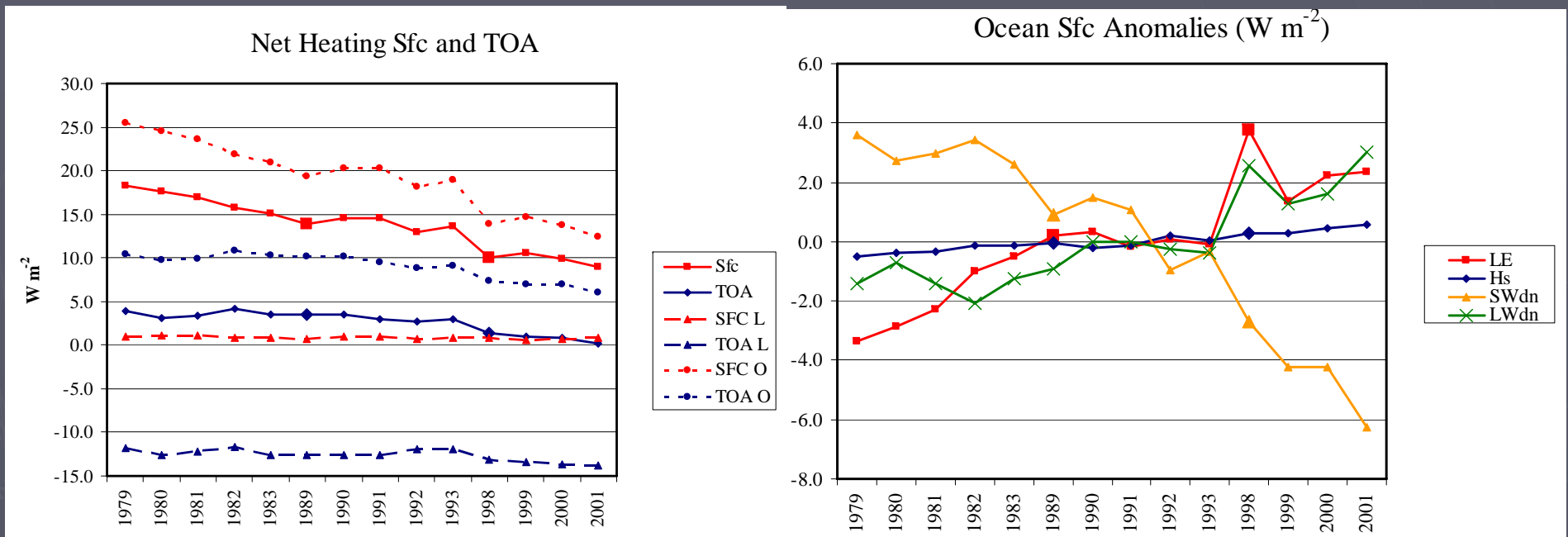


Global Heating Rates (W m^{-2})



- ▶ Global P trend mostly over Ocean, and corresponds to Q_v Increments
- ▶ Atm Latent heating variations anti-correlated to heating increments

Net Surface and TOA Imbalance



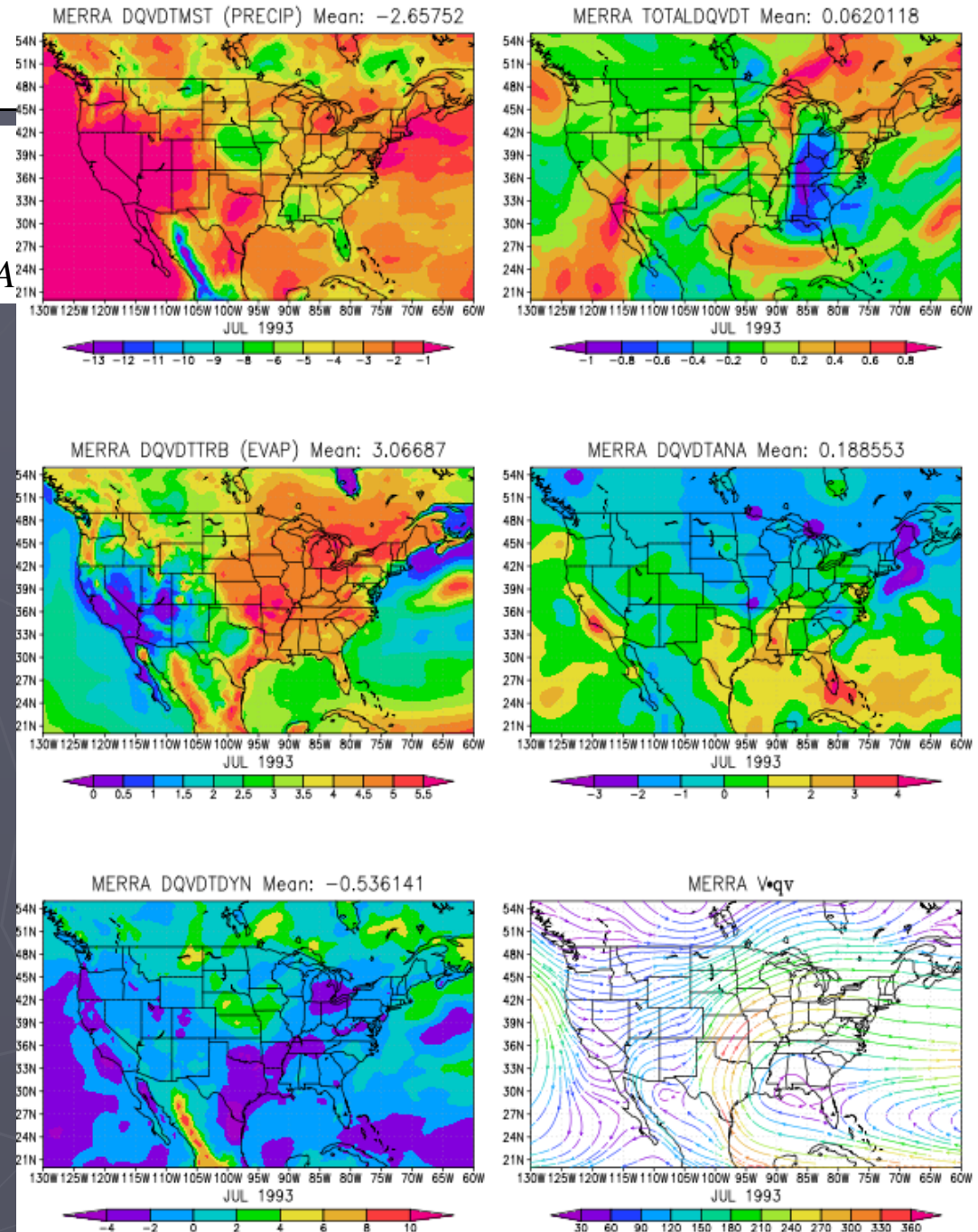
- ▶ Global surface net imbalance is improving in time, mostly changing over Ocean
- ▶ The Ocean net imbalance is decreasing in incoming SW radiation and increasing LE

Vertically-Integrated Water Vapor Budget for July 1993

$$\frac{\partial q_v}{\partial t} = E - P - \nabla \cdot q_v + \frac{\partial q_v}{\partial t}_{ANA}$$

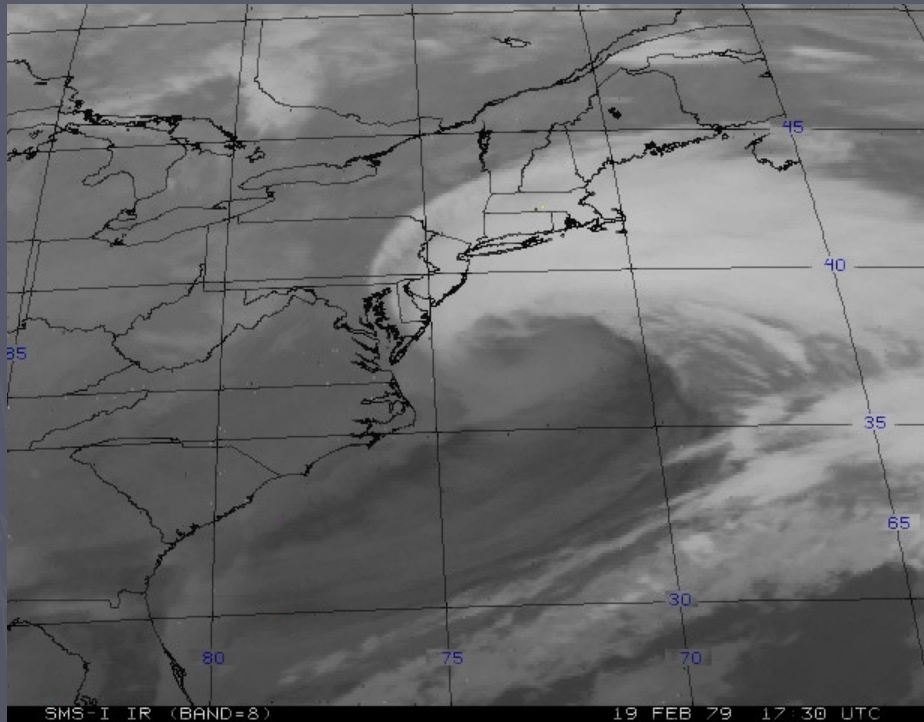
- ▶ Complete budgets are available including all tendencies and analysis increments
- ▶ Water (all phases), Ozone, KE, Enthalpy, Included
- ▶ Also, land-only budgets
- ▶ Tremendous effort by Max Suarez, Larry Takacs and Randy Koster

MERRA WATER BUDGET PLOTS <http://gmao.gsfc.nasa.gov/merra>

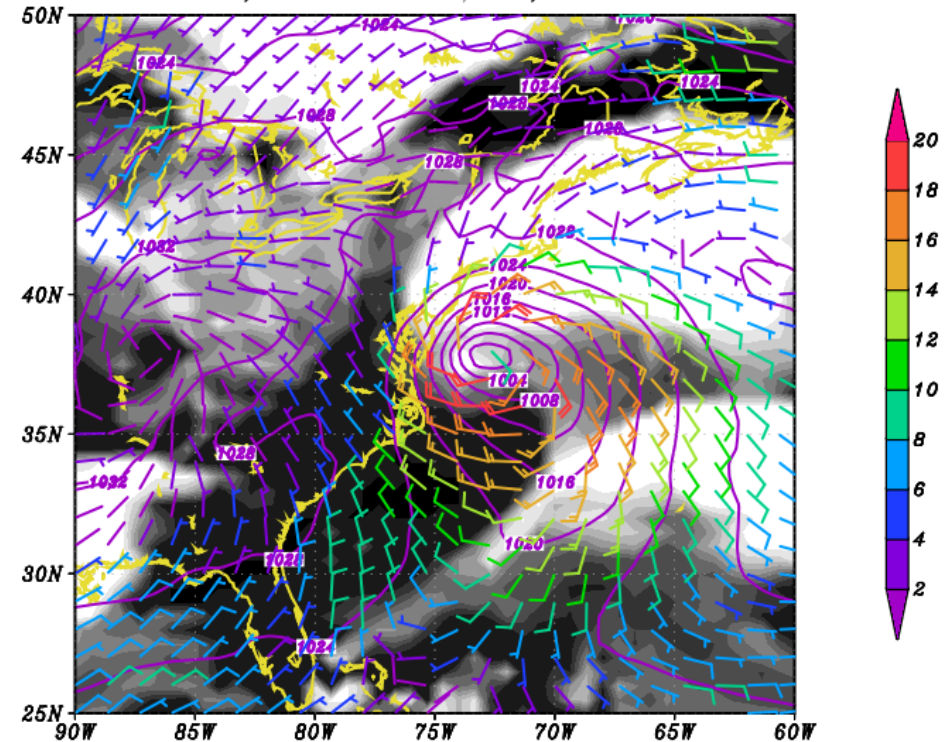


Presidents Day Snow Feb 19, 1979

GOES IR 17:30Z19FEB1979



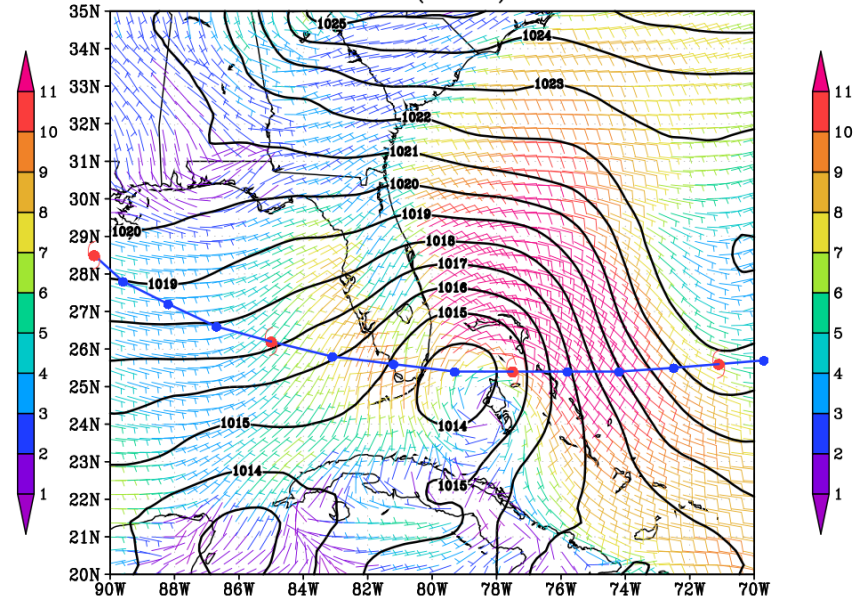
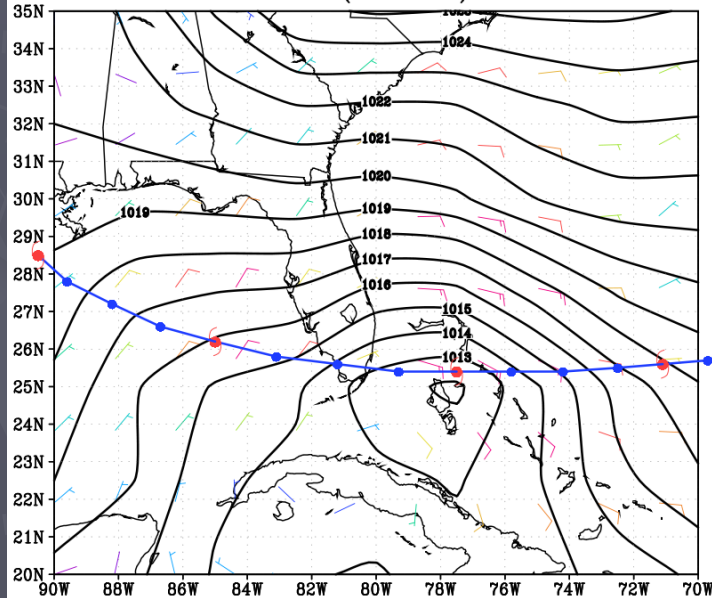
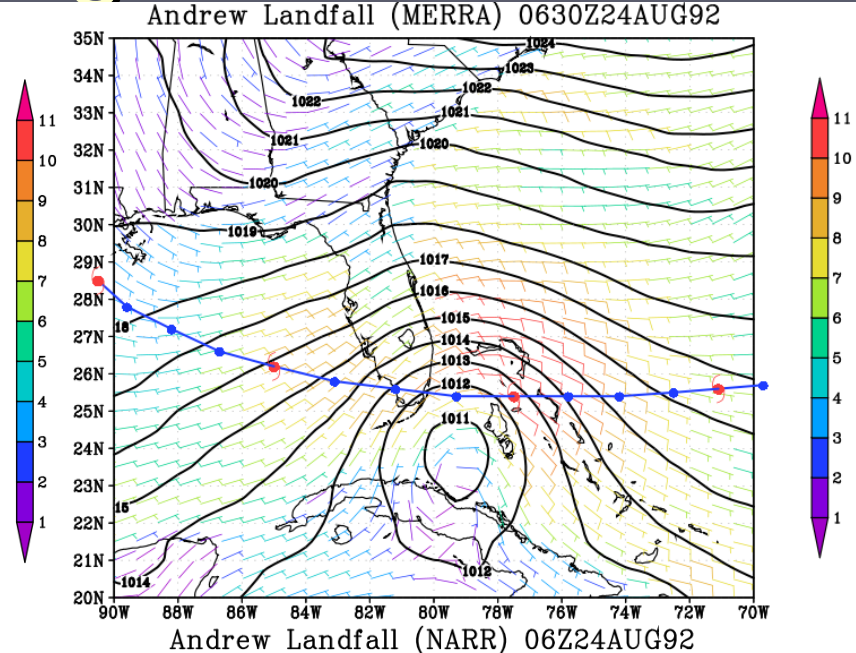
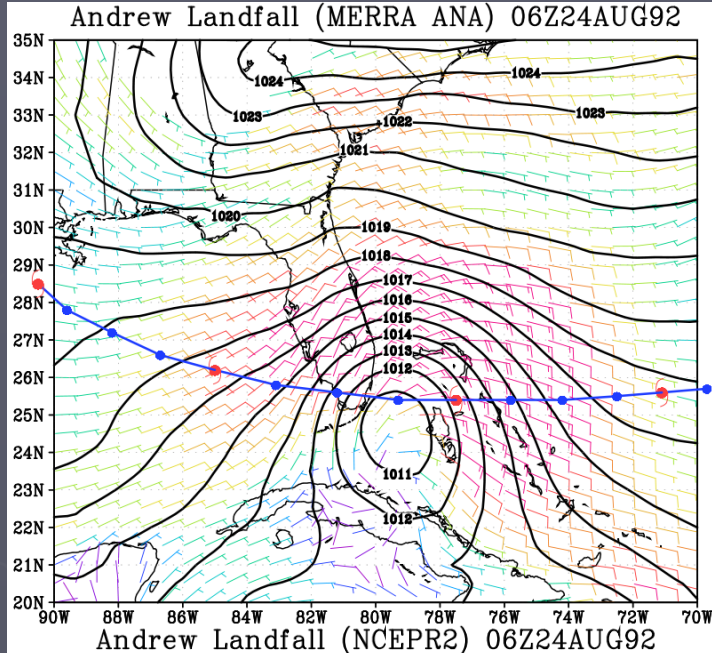
MERRA Clouds, Wind and SLP, 17:30Z19FEB1979



(Barbs every other grid space)

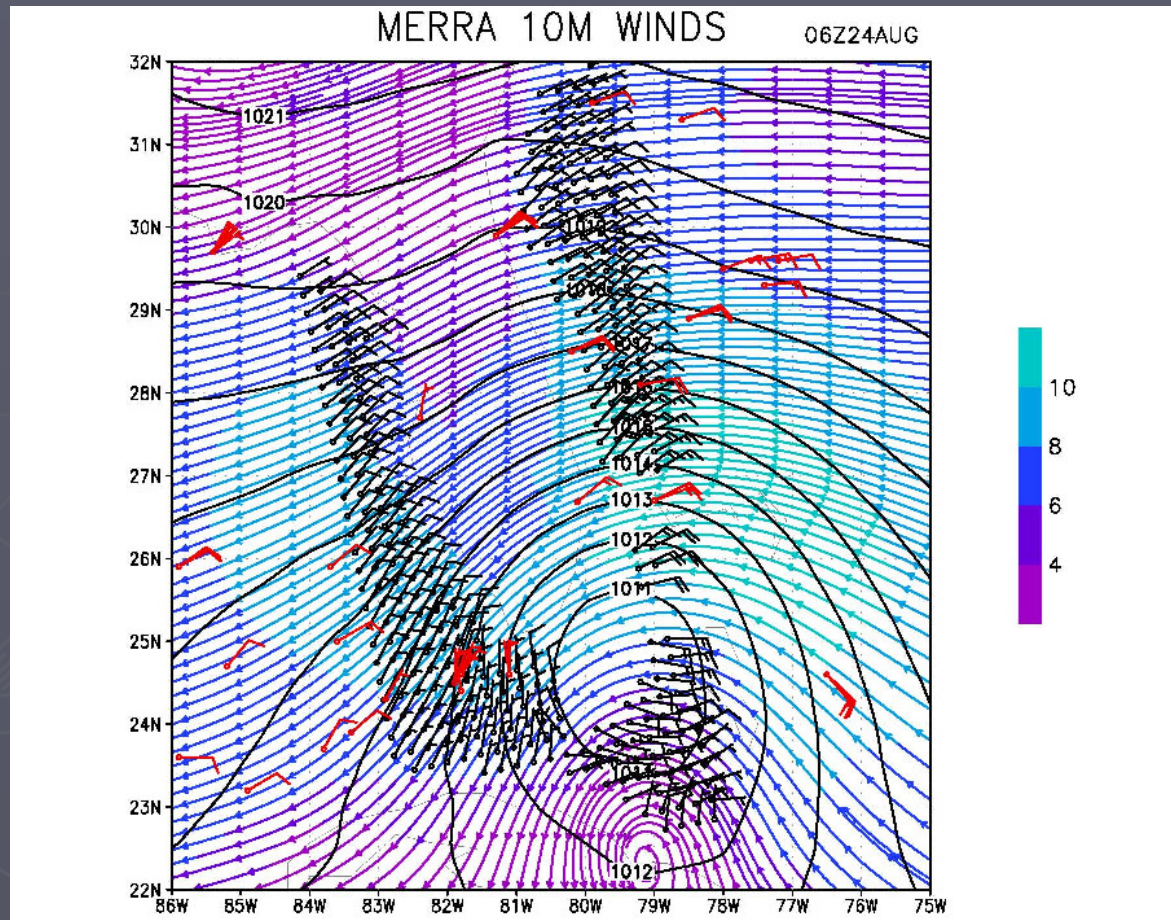
- ▶ Much fewer observations early in the record, still weather can be reasonable

Andrew Aug 24, 1992



► MERRA analyzed center is south of observed

Andrew Aug 24, 1992

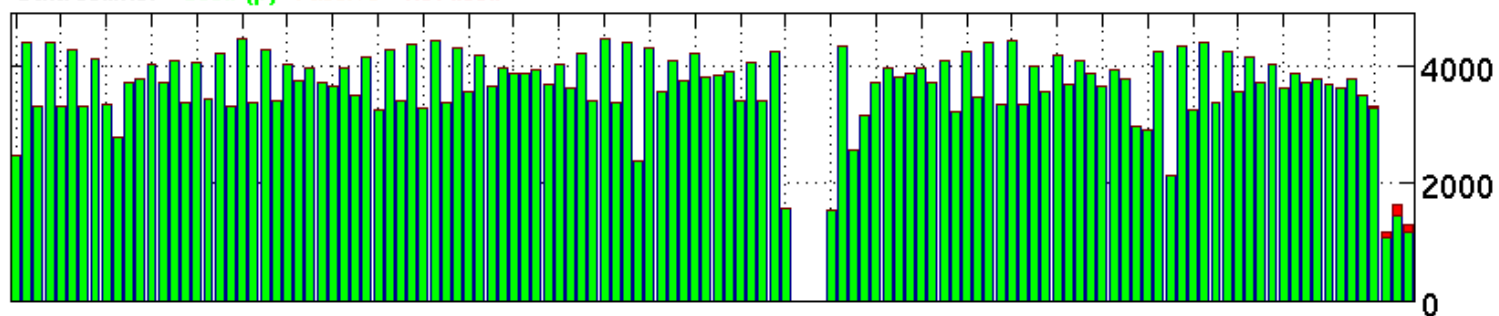


- ▶ Contaminated ERS1 data is used
- ▶ Resolution still too coarse for small TCs

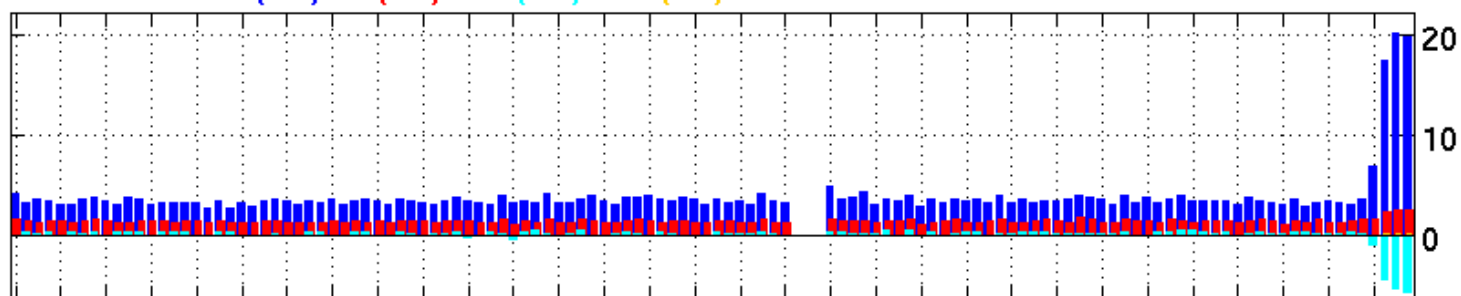
b5_merrasc_jan79 01Mar1992 00Z - 31Mar1992 18Z

All ozone data (Global)

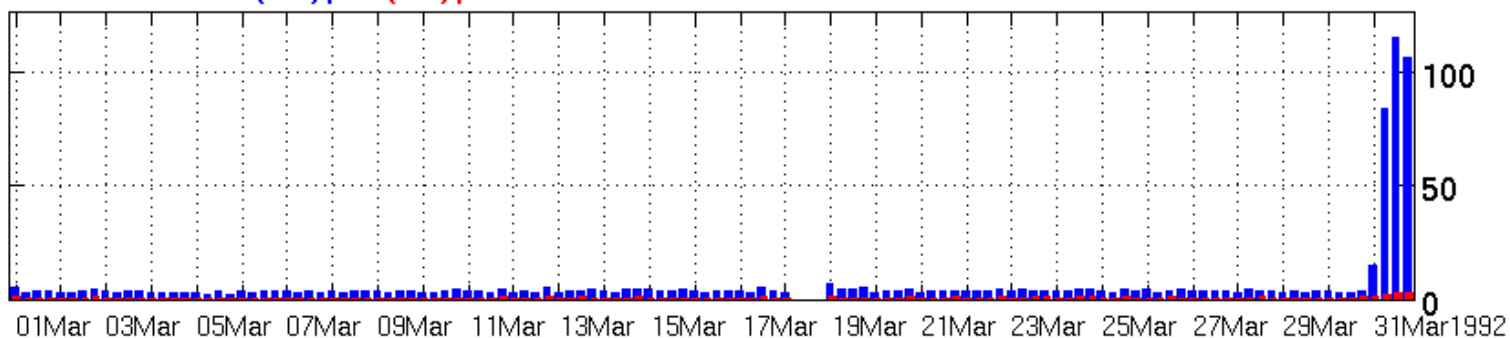
Data counts: Used (p) Passive Not used



Data residuals: rms(O-B) rms(O-A) mean(O-B) mean(O-A)



Normalized cost: Jo(O-B)/p Jo(O-A)/p

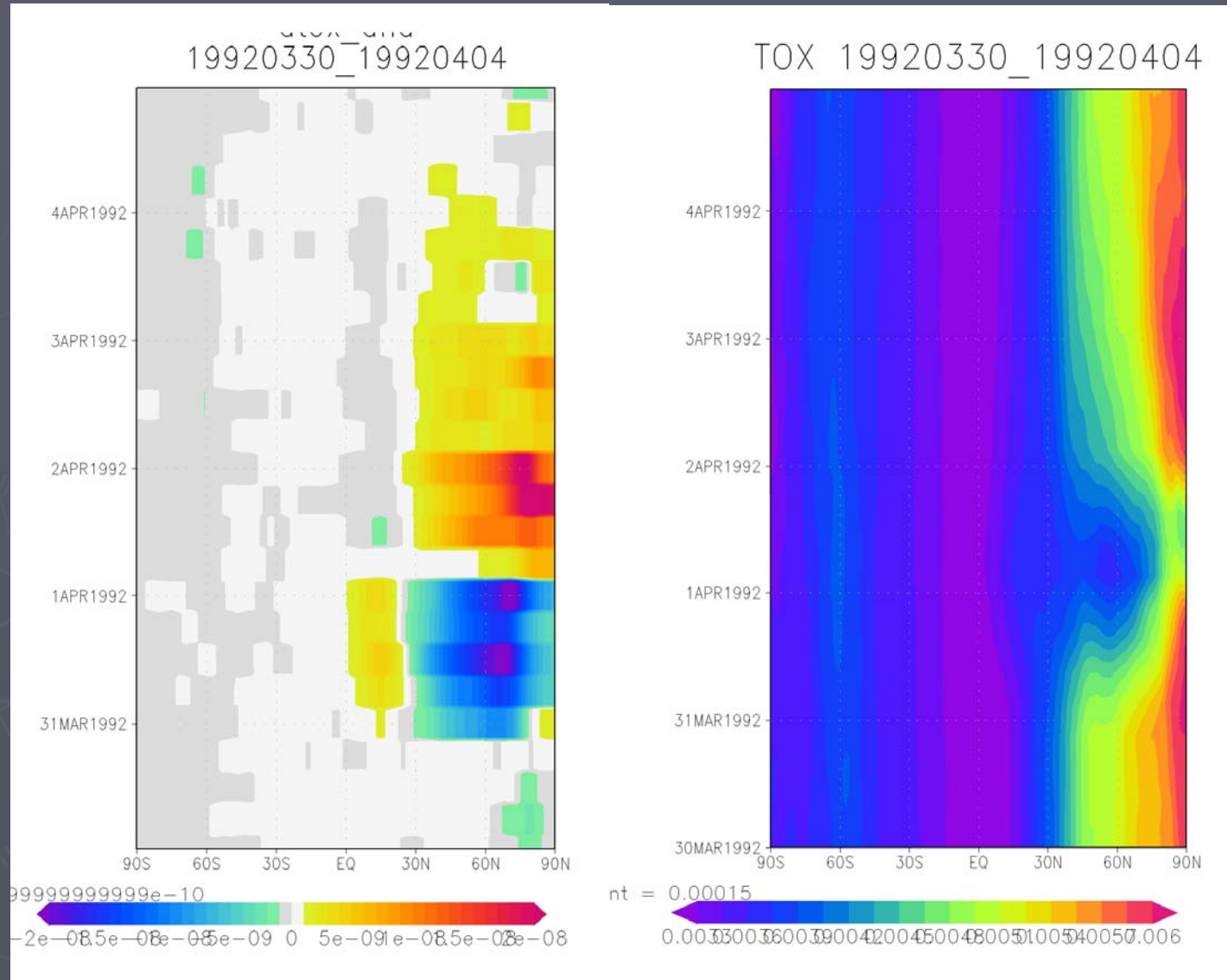


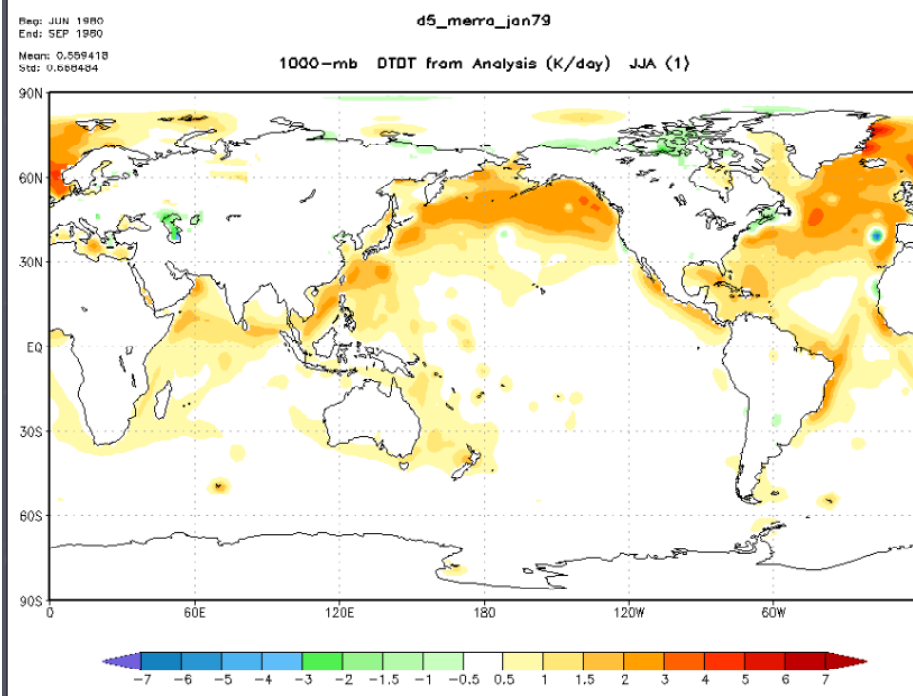
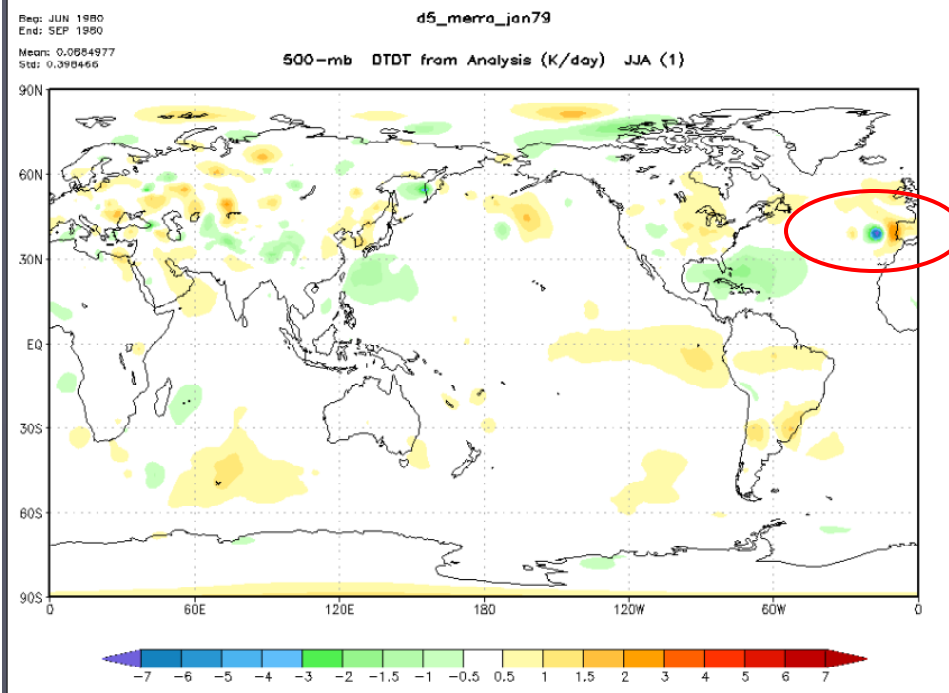
Scout SBUV Assimilation Statistics, Mar 1992

Ozone response to questionable data

Increments

Ozone





Flawed sounding: Azores

- ▶ 1979-1980: A persistent sounding west of Portugal is very different from others nearby
- ▶ The result is a persistent counter-increment that affects energetics and moisture budgets

MERRA On-Line Atlas

GMAO - MERRA

http://gmao.gsfc.nasa.gov/research/merra/prequel/view.php?&mstream=d5_

NASA Goddard Space Flight Center
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+ MERRA Home

MERRA

MERRA MULTI-STREAM VISUALIZATION
See [README](#) · [MERRA Progress & Events](#)

1 CHOOSE STREAM (EXPID) 2 SELECT YEAR 3 CHOOSE COMPARISON

d5_merra_jan79 Y1981 JRA25 Reanalysis

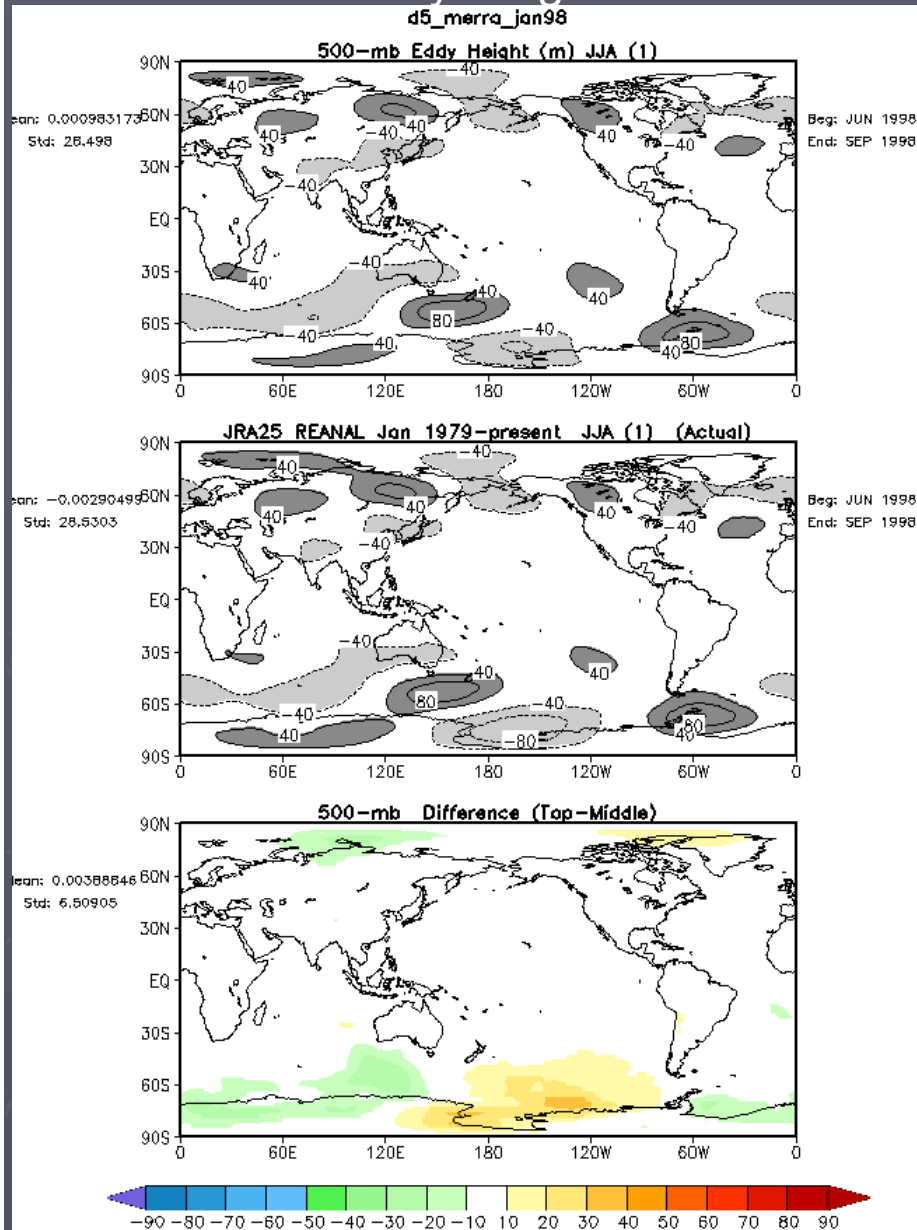
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DJF	MAM	JJA	SON	ANN
Observing System	go	go	go	go	go	go	go	go	go	go	go						
ZM UWND	go	go	go	go	go	go	go	go	go	go			go	go	go		
ZM VWND	go	go	go	go	go	go	go	go	go	go			go	go	go		
ZM TEMP	go	go	go	go	go	go	go	go	go	go			go	go	go		
ZM Q	go	go	go	go	go	go	go	go	go	go			go	go	go		
850mb Eddy Heights	go	go	go	go	go	go	go	go	go	go			go	go	go		
500mb Eddy Heights	go	go	go	go	go	go	go	go	go	go			go	go	go		
300mb Eddy Heights	go	go	go	go	go	go	go	go	go	go			go	go	go		
850mb Temp	go	go	go	go	go	go	go	go	go	go			go	go	go		
200mb UWND	go	go	go	go	go	go	go	go	go	go			go	go	go		
200mb VWND	go	go	go	go	go	go	go	go	go	go			go	go	go		
850mb Q	go	go	go	go	go	go	go	go	go	go			go	go	go		
SLP	go	go	go	go	go	go	go	go	go	go			go	go	go		
TPW																	
Precip																	
Precip All	go	go	go	go	go	go	go	go									
Precip Diffs	go	go	go	go	go	go	go	go									
Precip Taylors	go	go	go	go	go	go	go	go									
Precip Adv. Taylors	go	go	go	go	go	go	go	go									

- ▶ Updated regularly with monthly comparisons versus existing reanalyses and some global observed data sets
- ▶ More comparisons being added and will be redone at the completion of MERRA
- ▶ Beta Version:
Comments Welcome

<http://gmao.gsfc.nasa.gov/research/merra/prequel/view.php>

Example figures from the Atlas

500mb Eddy Height vs JRA25

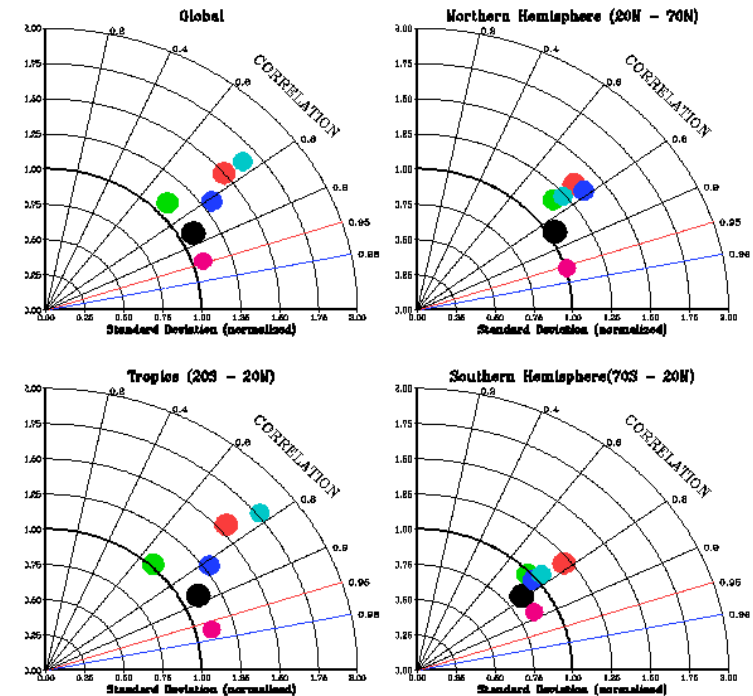


Precipitation Taylor Diagram, All Reanalyses using GPCP as the reference

d5_merra_jan98

199807

d5_merra_jan98 v. GPCP
NCEP-R2 v. GPCP
NCEP-R1 v. GPCP
JRA-25 v. GPCP
ECMWF ERA-40 v. GPCP
CMAP v. GPCP



MERRA Documentation

- ▶ GEOS5 Model and Assimilation Document, Rienecker et al., 2008: NASA/TM-2008-104606, V27
- ▶ MERRA File Specification, Suarez et al. (Outlines the output data format, and information on variables)
- ▶ MERRA Validation, Bosilovich et al. (Results of the GEOS5 Validation Experiments, prior to beginning MERRA production)